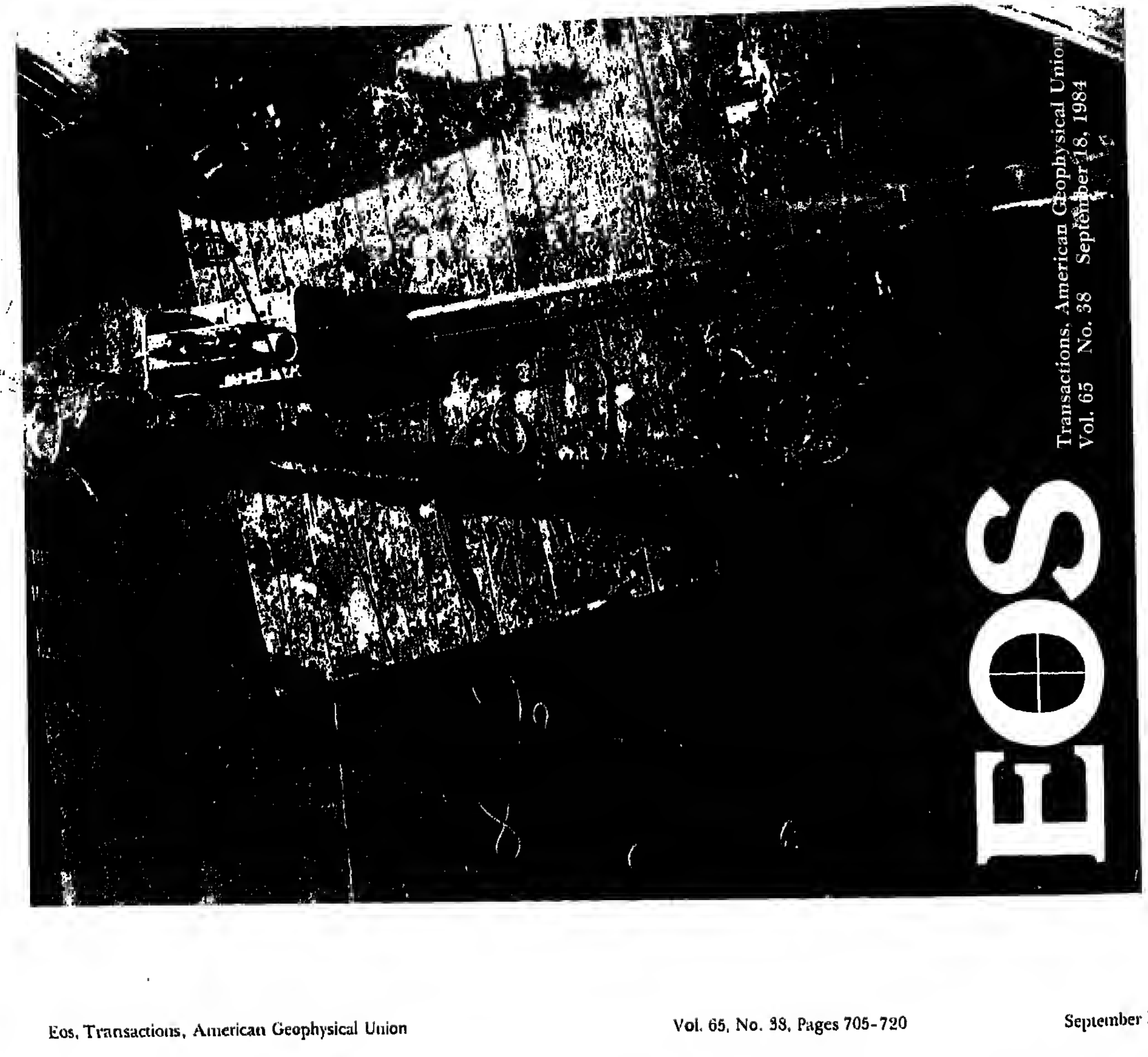

EOS

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Fall Meeting Housing and Registration Forms, page 712

Eos, Transactions, American Geophysical Union   Vol. 65, No. 38, Pages 705-720   September 18, 1984

Volcanology

5599 Volcanology topics
GEOMETRICAL FORM OF ASEISMIC RIDGES, VOLCANOES, AND SEAMOUNTS
C. L. Angevine (Department of Geological Sciences, Cornell University, Ithaca, New York, 14853), D. L. Turcotte
Many volcanic structures have a regular geometrical form that suggests a simple and universal mechanism for the growth. We suggest that the surface of these volcanic structures is a surface of constant hydraulic potential. When an eruption begins it follows a path to the point on the surface that has the minimum hydraulic resistance. This resistance includes both the frictional resistance to the flow and the gravimetric potential associated with elevation. We determine the shape of a two-dimensional volcanic edifice formed from a line source and compare the shape with bathymetric profiles across several aseismic ocean ridges. We also compare the predicted shape of an axisymmetric volcanic edifice formed from a point source with several profiles from the Cascade Range in the western United States and with a number of volcanic islands and seamounts in the Pacific.
J. Geophys. Res., B, Paper 4B0772

5199 Volcanology Topics
THE LONG VALLEY/MONO BASIN VOLCANIC COMPLEX: A PRELIMINARY MAGNETOTELLURIC AND MAGNETIC VARIATION INTERPRETATION
J. F. Hermance (Department of Geological Sciences, Brown University, Providence, RI 02912), W. M. Slocum, and G. A. Neumann
The Long Valley/Mono Basin volcanic complex is one of the few major silicic caldera systems in western North America that may still be potentially active. Magnetotelluric measurements offer a significant opportunity to study such systems through mapping subsurface electrical features associated with hydrothermal and magmatic processes in the crust. Our studies in this area, however, indicate that such techniques are profoundly affected by the highly three-dimensional structures associated with these complicated volcanic terranes. Simple plane-layered (one-dimensional) interpretations are likely to be misleading in such a complicated three-dimensional environment. On the other hand magnetotelluric observations can delineate important physical features associated with caldera structures; in particular, the method can closely determine the location and magnitude of major boundary faults. In addition, measurements at sites in the south moat of Long Valley caldera indicate the presence of a structurally controlled east-west electric current system at relatively shallow depth in the crust. This elongated east-west zone is aligned along the belt of recent seismic activity in the southwest moat, a zone of seismic shear wave attenuation, and a zone of known hydrothermal alteration at the surface. Finally, observations from the vicinity of Mono Craters, which have been thought to be associated with an active incipient caldera, do not indicate an observable decrease in resistivity at shallow depth. We conclude that the parent magma body feeding Mono Craters (and perhaps Inyo domes) is either too thin or too deep to be resolved, or is significantly displaced from a position beneath the center of the inferred ring fractures.
J. Geophys. Res., B, Paper 4B0361

5199 Volcanology
SULFUR DIOXIDE AND PARTICLES IN QUIESCENT VOLCANIC PLUMES FROM POAS, ARENAL, AND COLIMA VOLCANOES, COSTA RICA AND MEXICO
T. J. Casadevall (U. S. Geological Survey, 5400 MacArthur Blvd., Vancouver, WA 98661), W. I. Rose Jr., W. H. Fuller, W. H. Hunt, M. A. Hart, J. L. Moyers, D. C. Woods, R. L. Chuan, and J. P. Friend
Measurements of SO_2 emission rates and concentrations and of particle distribution, size, shape, and composition were made in quiescent volcanic plumes emitted into the troposphere from Poas and Arenal volcanoes, Costa Rica, and Colima volcano, Mexico. SO_2 emission rates were 700±180 metric tons per day (t/d) for Poas, 210±30 t/d for Arenal, and 320±50 t/d for Colima. The concentrations of SO_2 calculated from the COSPEC/LIDAR data were 5-380 ppb. Concentrations of SO_2 measured directly by flame photometry were 10-250 ppb. Particles collected in the plumes with a quartz crystal microbalance impactor were mostly less than 3 micrometers (μm) in diameter and consisted of droplets of dilute sulfur-bearing solutions and minor amounts of larger silicate particles coated with a sulfur-bearing film or crust. Total particle concentrations were 4.7 μg/m³ for Poas and 18.5 μg/m³ for Colima. Comparison of concentrations of SO_2 in the plumes with gas samples collected at fumaroles on the ground suggests that the plumes are diluted by the atmosphere by factors of up to 10^5. (Volcanic plumes, sulfur dioxide, particles, atmosphere chemistry)
J. Geophys. Res., D, Paper 4D0513

Research Drilling at Inyo Domes, Long Valley Caldera, California

J. C. Eichelberger and P. C. Lysne
Sandia National Laboratories, Albuquerque, NM 87185

L. W. Younker
Lawrence Livermore National Laboratory, Livermore, CA 94550

A 150-m hole has been cored through Obsidian Dome, and drilling is in progress to reach the conduit of Obsidian Dome and the dike believed to underlie the dome chain.

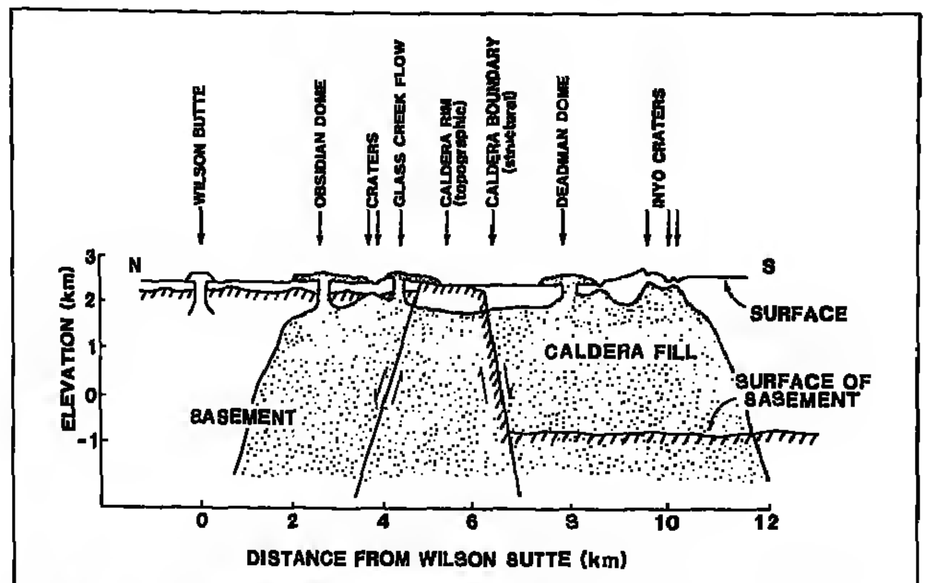


Fig. 2. Cross section along the Inyo trend. The postulated Inyo Dike reaches the surface at Obsidian Dome, the Glass Creek Flow, and Deadman Dome and the near surface beneath the contemporaneous phreatic craters.

Introduction

While a great deal of attention has been focused on inferring conditions within deep magma reservoirs, much of the action in terms of magmatic processes such as degassing, explosive fragmentation, and fluid/melt interaction occurs at depths of a few hundred meters to a few kilometers. Our understanding of what happens to magma in this important subvolcanic regime is primitive and inconsistent. For example, eruption models assume that magma is a chemically closed system during ascent, but geochemical models tacitly assume it is an open system (but only to H_2O and perhaps a few other volatile components). Thermal models are well developed but untested. The extent of magma/wallrock/fluid interaction is unknown. Yet we must understand the processes in this regime not only to understand the mechanisms of explosive eruption and hydrothermal circulation but to correctly interpret evidence of deep plutonic conditions as well.

The only way to address these problems properly is by direct observation of young subvolcanic intrusions. Fortunately, much of the required information can be obtained with standard drilling and coring techniques at costs similar to surface geophysical observations. Samples and conditions in the intrusive environment record the response of magma and host to rapidly changed pressure and temperature conditions on a time and size scale that cannot be duplicated experimentally. Among the unique kinds of data that drilling can provide are temperatures in and near a cooling intrusion, composition of pristine intrusive glass representing magma quenched under known load, and the structure and composition of the intrusive portion of a system for which the eruption history and eruption product composition are well known. In the areas of mechanical effects of intrusion and mass transfer between magma and host, drilling can provide a far higher quality of data than sampling of exposed fossil systems through the generally greater continuity of the section sampled and the knowledge that the intrusion and its environment have been unaltered by subsequent, unrelated geologic events.

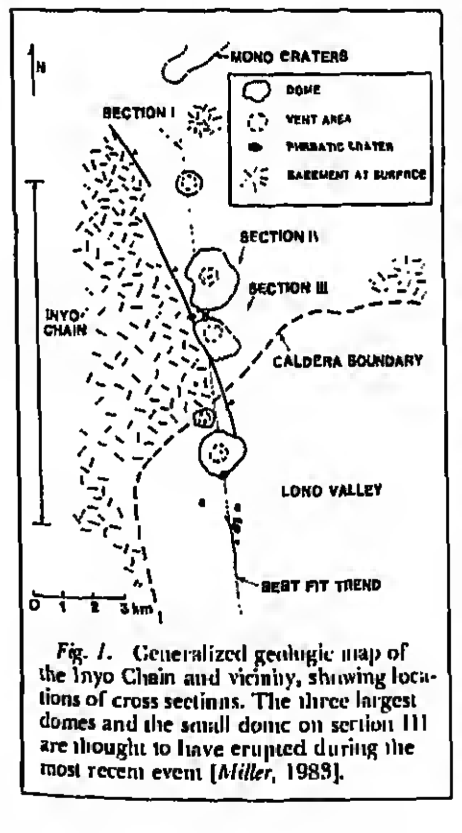


Fig. 1. Generalized geologic map of the Inyo Chain and vicinity, showing locations of cross sections. The three largest domes and the small dome on section III are thought to have erupted during the most recent event [*Miller*, 1985].

A program of research drilling has begun at the Inyo Domes volcanic chain which cuts north-south across the northwest rim of Long Valley Caldera (Figure 1). The youngest features of the chain (four magmatic vents, at least six phreatic vents, and associated normal faults) are believed to be the surface expression of a dike or system of dikes which is at least 8 km long and was emplaced approximately 600 years ago [*Miller*, 1985] (Figure 2). During October 1983, a vertical 150-m hole was cored through Obsidian Dome, northernmost of the young magmatic vents. Work is now underway on a 600-m slant core hole to intersect the conduit which fed Obsidian Dome and a 1000-m slant core hole to intersect the Inyo Dike between Obsidian Dome and the Glass Creek Flow. Additional holes, both inside and outside the caldera, have been proposed for subsequent years.

Both the drilling and supporting research are funded by the Office of Basic Energy Sciences of the U.S. Department of Energy (DOE). As an investigation of processes of heat and mass transport in an anomalously hot region of the earth's crust, this effort represents part of the national Continental Scientific Drilling Program (CSDP). Inyo drilling was initiated under a proposal for shallow drilling at Long Valley, Valles Caldera, and Salton Sea submitted to DOE in 1983 by four DOE labs. The broader program described here is an outgrowth of the initial shallow drilling effort and resulted from a proposal submitted to DOE in 1984 by a consortium consisting of three national laboratories, the U.S. Geological Survey, and five universities. Participants are listed in Table 1.

Scientific Objectives

The Inyo chain is particularly well suited for research drilling for a number of reasons: (1) Although dike propagation is thought to be the dominant mode of magma movement in the subvolcanic regime [*Pollard et al.*, 1983], at very few sites can the position of a young dike be as well constrained from surface evidence as at Inyo Domes. (2) As the most recent rhyolitic magmatic event in the western United States, the intrusion should be neither thermally equilibrated nor the glass of the intrusion hydrated. (3) Because the Inyo Chain cuts across the structural boundary of the caldera, the dike is emplaced in two contrasting environments pertinent to consideration of continental volcanism. One is thick, porous, permeable, and water-saturated volcanic pile represented by the caldera fill. The other is silicic crystalline basement, represented by Sierran granitic rocks. (4) Finally, the dike is the most recent leak from the evolving Long Valley Caldera magma system [*Bailey et al.*, 1983] and an accessible analog to intrusions which may be forming now at greater depth beneath the seismically and tectonically active southwest caldera moat and the resurgent dome [*Hermance*, 1983].

The scientific objectives for drilling the Inyo system are to characterize and compare the thermal, chemical, and mechanical behavior of magma in the contrasting environments of caldera fill and crystalline basement. In discussing how these objectives are to be achieved, it is useful to consider the zones that should be penetrated by a core hole slanted into a conduit or dike. The intrusion itself should consist of an outer quenched glassy zone and a crystalline interior, while the host can be divided into a far-field undistrubed zone and a near-field disturbed or contact metamorphic zone. The importance of sampling and analyzing the undisturbed host is that it represents initial, pre-intrusion conditions. The contact metamorphic zone represents host material altered by the intrusive event. Processes contributing to these changes may include dike propagation, rapid heating to high temperature, and circulation of hot fluids of magmatic or meteoric origin.

The next zone to be encountered will be the quenched, glassy outer portion of the intrusion. This material is of special importance because it records the state of the magma in terms of phase assemblage, phase composition, and bulk composition including volatile content at the time of intrusion. It will differ from surface samples because it was quenched while under substantial pressure and from the quenched margins of exposed fossil intrusions because it is sufficiently young that it has not been contaminated by meteoric water through hydration. In terms of geochemical observations, the data should be comparable to what could be gained by coring into an active magma body.

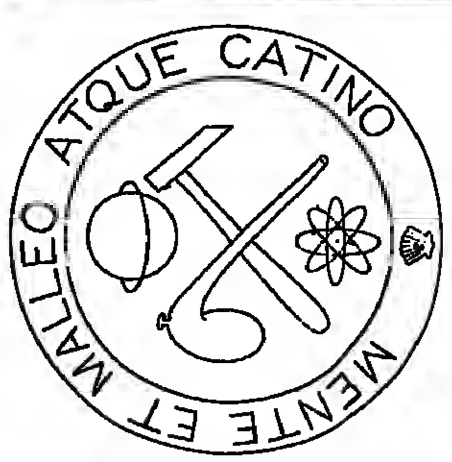
As the drill penetrates deeper into the intrusion it will encounter magmatic material which cooled more slowly, with the result that higher crystal content and lower glass content should be expected. Important factors controlling crystallization behavior are likely to be retained magmatic volatile content and cooling rate, and these will vary with depth and distance from the contact. In order to gain maximum information on intrusion geometry and the character of each zone, holes will be planned so as to completely penetrate their magmatic targets.

Perhaps the most basic observations to be made in the drill holes are the position and orientation of intrusions relative to their surface volcanic expression. The model to be tested, but which we are confident enough about to use as a basis for siting the holes, is that a long, near-vertical dike extends upward to shallow depth (few hundred meters) and joins large-diameter conduits which continue to the surface at the magmatic vents [*Miller*, 1985; *Fink and Pollard*, 1983]. Information about the size and structure of the dike and conduits will provide insights into the eruption process, since the eruption history at the surface is well known. Likewise, surface geochemical data will be compared with composition of the intrusive portion of the system. It is usually assumed that, given sufficient care in sampling, samples collected at the surface from eruption products are a faithful representation of magma chemistry in the parent chamber, with the exception of gases lost during eruption. This concept, although universally used, has never been tested. Processes that may lead to differences between the extrusive and intrusive portion of a system include vapor transport during degassing and magma-wallrock interaction. In addition, batches of magma may remain unchanged during ascent, but tapping of a zoned chamber or mixing of magmas from different chambers may result in changing composition with time during eruption and lead to differences betweeen the extrusive and intrusive portions of the sytem [*Bailey et al.*, 1976, 1983].

Another very basic observation to be made is temperature. High temperatures due ultimately to magmatic heat have been observed at depth in many areas but not where the heat could be attributed to a single, well-defined intrusive event. Observations of elevated temperatures due to individual magmatic events are limited to extrusive bodies. Drilling the Inyo system will provide an opportunity to directly observe the cooling process and to determine the relative roles of conduction and convection in two environments of contrasting permeability. Calculations (J. C. Dunn, unpublished data, 1984) show that if the dike is 10 m or more wide and cooled dominantly by conduction, then magmatic heat will still be detected only a few hundred meters below the top of the basement and will have diffused outward approximately 500 m.

Observation of retained magmatic volatile content in the glassy chill zone will provide new information on how magmas degas.

Article *(cont. on p. 723)*



"Mind and Mallet and Crucible"
(Originally appeared in *The Geochemical News*, 9, 5, 1958.)

Editor: Bruce Doe, 11721 Dry River Court, Reston, VA 22091 (telephone 703-860-3470, after 5:30 p.m.).

Understanding Thermal Energy and Dynamic Processes in Subduction-Related Volcanic Arcs: Proposed Studies in the Cascades

George R. Priest and David D. Blackwell

The importance of subduction-related volcanic arcs in the geologic record and in the record of historic earthquakes and volcanic eruptions is hard to overstate. Subduction-related terranes appear to be represented in the geologic record from the Archeozoic to modern times and account for much of the world's volcanic activity. Convergent plate margins stretching for thousands of miles around the Pacific, the Caribbean, the Indian Ocean, and the Mediterranean have some of the most active volcanoes and largest geothermal systems in the world. Many of the world's largest hydrothermal ore deposits are associated with calc-alkaline magmas injected into the crust as a result of the subduction process. The enormous deposits in the Andes, Indonesia, Japan, western North America, and other areas around the Pacific are examples.

The Cascade Range is the only presently active subduction-related volcanic arc in the conterminous United States. Active volcanoes related to the arc occur over a distance of over 1,300 km from British Columbia to northern California. The most destructive historic volcanic eruption in the United States occurred in 1980 at Mount St. Helens in the Washington part of the range. Partly because of its unique status, the Cascade Range is also one of the most completely studied volcanic arcs in the world. In spite of the extensive geologic and geophysical data available for the range, the detailed subsurface geology is essentially unknown because the thick sequences of young volcanic rocks effectively mask deeper structures. The high porosity, permeability, and resistivity and the low seismic velocity of young volcanic rocks in the most active part of the arc make geophysical sounding very difficult.

Geophysical techniques have been much more successful in the Western Cascades than in the young volcanic rocks of the High Cascade Range to the east. The Western Cascade Range is Miocene and older volcanic terrane which has been diagenetically and hydrothermally altered, greatly decreasing the porosity and permeability of the rocks.

One of the most significant findings from studies of the Western Cascade Range is in the area of heat flow. The results of heat flow measurements in numerous drill holes indicate that there is a heat flow anomaly with a half width of approximately 10 kilometers on the western side extending from northern California to southern British Columbia [*Blackwell and Steele*, 1983]. Heat flow increases by as much as a factor of 2 or more across the western side of this anomaly, and the average geothermal gradients within the main part of the anomaly in the Oregon Cascade Range are about 65°C/km [*Blackwell et al.*, 1978, 1982]. On the basis of the interpretation of these data, it appears that temperatures appropriate for partial melting of granitic material should occur at depths on the order of 7 to 10 kilometers under the easternmost part of the Western Cascade range in Oregon [*Blackwell et al.*, 1978, 1982]. These depths are similar to depths estimated for partially molten granitic bodies under silicic volcanic centers such as the Yellowstone, Long Valley, and Valles calderas. Temperatures at equivalent depths beneath the High Cascade Range may be even higher, but thus far attempts to measure heat flow in the High Cascades have been thwarted by the rapidly circulating shallow groundwater which washes away heat flow in the carapace of young volcanic rocks. Lack of reliable heat flow data in the High Cascade Range is one of the principal reasons that its geothermal resources are not generally included in estimates of the accessible geothermal resource base for the United States. If geothermal systems are present in a significant part of this enormous province, they could dwarf the geothermal potential estimated for the largest silicic volcanic centers in the United States.

Rationale for Scientific Deep Drilling in the Cascades

The previously mentioned problems presented by the cover of young volcanic rocks in the Cascades can only be solved by drilling. Experience in drilling in areas such as Newberry Volcano in Oregon has shown that drill holes must generally be 1 km or deeper in order to make meaningful measurements of heat flow in the youngest part of the volcanic arc. Drill holes deeper than 1 km are almost completely lacking in the young volcanic rocks of the High Cascades. Drilling to depths of 7–10 km would be necessary in order to test directly the hypothesis that temperatures near the melting point of granitic rocks occur at those depths. Should this hypothesis prove to be correct, it would have enormous consequences for estimates of geothermal potential and for physical models of subduction-related volcanic arcs throughout the world. It would mean that regional zones of very high temperature, possibly molten rock, occur at relatively shallow crustal levels under the entire length of active arcs regardless of the presence or absence of single large volcanoes. Measurements in drill holes in the Cascades would allow calibration of the extensive surface geological and geophysical surveys, which could then be applied to other, less well-studied areas of the world. The drilling program would thus test a fundamental hypothesis and provide a standard data base for investigating other similar regions throughout the world.

Program for Scientific Drilling in the Cascades

In recognition of the need for deep scientific drilling in the Cascades, a group of scientists who are actively pursuing research in the province have met several times to formulate a proposal. An initial meeting was held at the AGU conference in San Francisco last December, and a proposal is now in preparation for submission in early 1985. The thrust of the proposed project will be a coordinated program of drilling and surface geological and geophysical surveys along a series of east-west transects across the full width of the Cascade Range. The drilling will occur primarily in the young volcanic terrane of the High Cascades and will be completed in two phases. The bulk of the drilling during the first phase will be aimed at reaching depths of between 1.2 and 2.7 km in two transects of four wells each across two contrasting parts of the arc. Some surface surveys and shallower drilling are also contemplated during the first phase to characterize two lower-priority east-west transects. The four transects are targeted on the southern Washington Cascades, two localities in the central Oregon Cascade Range, and the northern California Cascades. The first phase would allow direct testing and modeling of the hydrothermal systems, measurement of the amplitude of the heat flow anomaly in the High Cascades, and direct sampling of basement rocks to determine the structure, state of stress, and other physical properties. The first phase will also include geologic mapping and a full range of geophysical surveys across both the High Cascades and the Western Cascades to investigate the overall geologic framework of the arc, including the configuration of the subducting oceanic plate and the development of the arc through time. The second phase would be aimed at directly penetrating the source of the regional heat flow anomaly at depths of 7–10 km. The second phase would be an extraordinary scientific and engineering accomplishment and would necessarily be preceded by a lengthy period of research and development. Whereas the proposal currently being prepared deals conceptually with the second phase, only work on the first phase will be addressed in the initial proposal.

The extensive knowledge gained from the proposed research in the Cascade Range will, when integrated with similar data from the proposed Trans-Alaska Lithosphere Investigation (TALI), give an accurate representation of the configuration of the major subducting plates and associated volcanism along the western margin of North America. TALI was recently organized by the U.S. Geological Survey and other groups to plan for drilling and areal studies along a north-south transect 1,400 km long across the full width of Alaska.

This article is partly intended as an announcement to alert various funding agencies and potential colleagues to the existence of the organizing group for Cascade scientific drilling. We invite participation from other scientists at this time or in the future as the activities become more specific. A proposal submission is planned for January or February 1985. If you are interested in participating in this project, you can obtain general information and information on Oregon geologic studies from George R. Priest at the Oregon Department of Geology and Mineral Industries, 1005 State Office Building, Portland, Oregon 97201 (telephone: 503-229-5580). The following persons are coordinating other aspects of the project:

Hydrology: Edward S. Sammel, U.S. Geological Survey, 345 Middlefield Road, M/S 39, Menlo Park, CA 94025.
Water Chemistry: Robert H. Mariner, U.S. Geological Survey, 345 Middlefield Road, M/S 27, Menlo Park, CA 94025.
Hydrothermal Alteration, Geologic Studies in the Northern California Cascades: Terry E. C. Keith, U.S. Geological Survey, M/S 910, Branch of Igneous and Geothermal Processes, 345 Middlefield Road, Menlo Park, CA 94025.
All Work in the Southern Washington Cascades: Craig Weaver, U.S. Geological Survey, Geophysics Program AK-50, University of Washington, Seattle, WA 98195.
Heat Flow: David D. Blackwell, Geothermal Laboratory, 253 Heroy Building, Southern Methodist University, Dallas, TX 75275.
Seismic Surveys: Walter Mooney, Douglas A. Stauber, and Mahadeva Iyer, U.S. Geological Survey, M/S 77, 345 Middlefield Road, Menlo Park, CA 94025.
Gravity and Aeromagnetic Surveys: Richard Couch, Department of Geophysics, School of Oceanography, Oregon State University, Corvallis, OR 97331.
Magnetotelluric Surveys: Harve Waff, Department of Geology, University of Oregon, Eugene, OR 97403.
Resistivity and Other Electrical Surveys: Norman Goldstein, Lawrence Berkeley Laboratory, University of California, Building 50, Room 1140, Berkeley, CA 94720.
Well Logging: Richard Traeger, Sandia National Laboratory, Division 6241, Albuquerque, NM 87185.

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Blackwell, D. D., D. A. Hull, R. G. Bowen, and J. L. Steele, Heat flow of Oregon, *Spec. Pap. 4*, 42 pp., Oreg. Dep. of Geol. and Min. Ind., Portland, 1978.

George R. Priest *is with the Department of Geology and Geophysics, Southern Methodist University, Dallas, TX 75275.* David D. Blackwell *is with the Oregon Department of Geology and Mineral Industries, Portland, OR 97201.*

News & Announcements

Lionel Wilson Wins VGP Award

Citation

Lionel Wilson (Department of Environmental Sciences, University of Lancaster, England) has brought physics to volcanology and transformed a largely descriptive and petrological science by development of a quantitative and predictive understanding of eruption dynamics. Lionel's involvement in volcanology started in 1971 when he helped George Walker determine the rates of fall of pyroclasts. This fairly simple problem led to questions of settling of ash particles onto the earth, and Lionel embarked on a series of papers that progressively traced volcanic debris back to its source crater. He described the physical processes affecting pyroclasts in strombolian and plinian eruptions, and with Steve Sparks and others modeled the formation (1976) and emplacement (1978) of ignimbrites by gravitational collapse of an eruption column. In a paper important to understanding the dispersal of tephra, Lionel and others demonstrated that eruption cloud heights are proportional to the fourth root of the mass eruption rate of magma (1978), leading ultimately to the inversion of the problem to deduce cloud height and associated eruption characteristics from mapped tephra distributions. The correctness and utility of Lionel's theoretical descriptions of explosive activity were demonstrated by a series of papers applying the models to actual eruptions at Fuego, Guatemala (1980), Ngauruhoe, New Zealand (1979), La Soufriere, St. Vincent (1982), and St. Helens, Washington (1982), as well as to tephra deposits at Askja, Iceland (1981), Toluca, Mexico (1977), and Thera, Greece (1978).

During the last few years, Lionel has turned his attention to volcanism in other parts of the solar system. Working with Jim Head and associates, Lionel derived mathematical models of the ascent and emplacement of basaltic magmas and applied these ideas successively to earth and moon (1981), Mars (1982), Io (1982), and Venus (1982). A good summary paper appears in *Nature* (*302*,663–669, 1983). The planetary work represents a testing and application of his models of pyroclastic dynamics to new environments and also the development of similar quantitative understanding of lava flow dynamics. Lionel and Jim Head thus were able to numerically account for peculiar features of lunar sinuous rilles and associated source craters (1981). On Mars, Lionel and coworkers discovered evidence for recent explosive activity on one of the shield volcanoes, and derived the cloud height, mass eruption rate, volatile content, and depth of magma storage (1982). For Venus, there is no direct evidence of the nature of volcanism, although chemical analyses of surface materials and geomorphology give persuasive evidence for past volcanic activity. However, Lionel's numerical models of explosive activity, adjusted to the high temperature and pressure of Venus, provide clues to possible volcanic processes and landforms seen on radar images. Lionel found that energetic eruptions on Io can be modeled if large proportions of volatiles are erupted at high eruption rates (1981).

Lionel Wilson has produced a series of major papers that numerically model nearly all aspects of eruption processes. His collaboration with leading volcanologists and planetary geologists has ensured that his models are geologically reasonable and widely accepted.

As the third winner of the VGP Award, Lionel Wilson provides further evidence for the successful application of fundamental physical, chemical, and mathematical principles to the understanding of geophysical and geochemical processes. (I am indebted to C. A. Wood for most of this citation.)

Joseph V. Smith

Acceptance

I am very grateful for your kind remarks about my work, Professor Smith. When I look at the field of volcanology, I see it with the eyes—and thought processes—of someone whose first interest was in basic physics rather than geology. The question of how we look at things—how we approach problems—has always intrigued me. I wonder if we are attracted to a particular scientific discipline as a result of our personal way of perceiving the world, or if we choose the discipline for some other reason and are then molded by the current conventions of that field. I would like to think it is the former, since the later has the inherent danger of suppressing new ways of thinking; but I am still not sure.

Many physicists—including me—look at the world in terms of simple processes. I recall once sitting on a cliff top overlooking a waterfall with a friend who was reading mathematics. Just to be provocative I said to her, "When you look at this waterfall, what interests you most? Is it the way energy conservation determines the speed of the water at the bottom in terms of the height of the fall, or is it the way the geometry of the system determines where the rainbow forms in the spray, or what?" I expected a response like, "You physicists are all the same: Why don't you appreciate it just because it's a beautiful view?" But instead she looked down and thought for a moment and said, "Don't you think a waterfall is too complex just to apply energy conservation? You really need the full fluid dynamics equation to treat a problem like that." Since then, I have felt much happier about the way physicists see the world.

Soon after I was graduated, I realized that it is much more interesting to work on applied problems than purely theoretical ones; this led me toward geophysics in general and quite soon into volcanology as the major theme of my research. I would certainly like to support the comments you made earlier, Professor Smith, about the importance of the interdisciplinary nature of the field, needing as it does input from many branches of geology, physics, and mathematics. I would also stress that as in other areas of earth science, we get a lot of extra information by viewing the earth as just one of a group of silicate planets. Studying eruptions on Io or Mars or the moon allows us to see the consequences of events taking place in environments with different values for the gravity or atmospheric pressure, and this is just a way of applying the classic technique of changing the boundary conditions and seeing how the system responds. I certainly feel that we should all be trying to expose our graduate students to the multi-planet data set as well as to the multidisciplinary approaches we have found so essential.

For those of us who, like me, did not have the benefit of all of these inputs during our early, formative years, the most efficient way of working involves collaboration with colleagues who have complementary backgrounds to our own, and I would like to pay tribute to my geological friends whose field experience and intuition help to keep me from wandering into the realms of fantasy too often. I have particularly benefitted from collaboration over many years with the scientists Professor Smith mentioned earlier: George Walker at Hawaii, Steve Sparks at Cambridge, and Jim Head at Brown. I would also like to mention the invaluable support I receive from my wife, Dorothy. She didn't make it to this meeting unfortunately; she found herself choosing between coming to Cincinnati or spending 6 weeks helping me in Hawaii in the summer, and strangely and by a very small margin of course, Hawaii won. Her background is not in science, as it happens, and so she is willing to listen without interrupting for far longer than anyone here in the audience would do to some of my more outrageous ideas. But having listened, she always tells me when something sounds like unmitigated nonsense, which is a great help. So, to the people I have mentioned specifically, to the many other colleagues who continue to provide stimulating ideas and constructive criticism, and to all of you for your kindness in presenting me with this award, my grateful thanks.

Lionel Wilson

Call for Contributions

The deadline for the January 1985 issue of The VGP News is November 30, 1984. Please submit all contributions to Bruce Doe.

Readers are also asked to inform the editor of The VGP News if they are interested in reviewing any recently published books. Input on what types of books and any specific suggestions for which books should be reviewed are also welcome.

Meetings

Microscopic to Macroscopic

The Mineralogical Society of America will sponsor a short course entitled "Microscopic-to-Macroscopic: Atomic Environments to Mineral Thermodynamics" before the 1985 annual Spring AGU meeting. An all-day symposium of invited and contributed related research papers will be held at AGU in Baltimore. The short course will be at Washington College, Chestertown, Md.

Speakers/authors for the short course are Charles Burnham (Harvard); Roger Burns (MIT); Michael Carpenter (Cambridge); Subrata Ghose (Univ. of Washington); Robert Hazen (Geophys. Lab.); Raymond Jeanloz (Berkeley); Susan Kieffer (USGS, Flagstaff); Desmond McConnell (Cambridge); Paul McMillan (Ariz. State Univ.); Alexandra Navrotsky (Ariz. State Univ.). The following topics will be covered: (1) characterization of atomic sites by various spectroscopic and crystallographic techniques; (2) the relations between atomic vibrational properties and spectroscopic properties; (3) calculation of thermodynamic properties from spectroscopic properties; (4) systematics of thermodynamic properties of minerals, including crystal-chemical constraints on free energies, phase transitions, heat capacities and entropies, solid solution effects, and isotopic fractionation. Authors are contributing examples of worked problems with their articles which will appear as a volume in the MSA series *Reviews in Mineralogy*.

The short course will consist of three morning lectures, two afternoon or evening lectures, and an evening workshop between Friday morning, May 24 and Sunday noon, May 26.

For further information, write to either (but not both) of the organizers: Alexandra Navrotsky, Department of Chemistry, Arizona State University, Tempe, AZ 85287; Susan W. Kieffer, U.S. Geological Survey, Flagstaff, AZ 86001.

Phreatomagmatic Eruptions

Special sessions on "Phreatomagmatic Eruptions and the Role of Water in Explosive Volcanism" are being held at the International Volcanological Congress, Auckland-Hamilton-Rotorua, New Zealand, February 1–9, 1986. In association with the Congress, there will be a special issue of a geological/geophysical journal dedicated to this topic; editing duties for the special issue are to be shared by conveners of the Congress and the IAVCEI Working Group on Explosive Volcanism.

Papers submitted for publication in the special issue should follow *Bulletin Volcanologique* format and must be carefully edited before submission for review. Manuscripts will be sent out for review, refereed, and final drafts collected by the special editors before submission to a journal. In addition to publication in a journal, the final drafts will be copied and circulated at the Congress.

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The deadline for manuscripts from authors to editors for processing and review is July 1, 1985.

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Cover. Coring through a 600-year-old obsidian flow near Long Valley Caldera, Calif. This hole, the first of a series to probe the subvolcanic environment of the Inyo Domes chain, penetrated 55 m of flow and bottomed at 152 m in precaldera andesite. (Photo by J. C. Eichelberger. See article, "Research Drilling at Inyo Domes, Long Valley Caldera, California," by J. C. Eichelberger, P. C. Lysne, and L. W.

Article (cont. from p. 721)

Through solubility data for various volatile species, vapor pressure at the time the system chemically closed can be inferred from volatile concentration and compared with the known lithostatic load. By sampling chill zones at multiple depths, the pressure (depth) dependence of degassing behavior can be determined. Alternatively, if no degassing occurs except in explosive fragmentation, volatile content will be independent of depth. For magma under lithostatic load at 1000 m, the solubility of water in melt is an order of magnitude higher than water contents observed in Obsidian Dome. Although it might be expected that degassing would result in water contents near the solubility curve, in fact equilibration with surface conditions (0.1 MPa) extends to at least 100 m (2 MPa) [*Eichelberger and Reece*, 1983]. While degassing to 1 atmosphere water vapor pressure is certainly not expected to extend to depths of 500 or 1000 m, glasses at these depths may be substantially water undersaturated (at magmatic temperature) if the magma behaves during ascent as a stiff, permeable foam.

The problem of dike emplacement will be investigated in detail. Fracture experiments will be used to characterize current conditions in the vicinity of the dike in terms of joint orientation and stress orientation and magnitude. Evidence for the mechanism of dike propagation is provided by fractures and other mechanical damage near the dike. Predictions of fracture distribution from existing dike propagation models [*Pollard et al.*, 1983] can be compared with actual fractures mapped from core examination and borehole televiewer studies, which may also reveal pathways of fluid flow relevant to the geochemical and thermal investigations.

Processes of mass transport within the dike and between the dike and its host will be investigated largely through trace element and isotopic techniques. The isotopic composition of oxygen and hydrogen is a sensitive indicator to processes involving water, such as magmatic degassing and interaction between meteoric water and magma [e.g., *Taylor et al.*, 1983]. The isotopic contrast between Sierra basement and Inyo magma for Sr and Pb isotopes will provide a sensitive test of the extent of assimilation [e.g., *Doe et al.*, 1969; *Lipman et al.*, 1978]. The glassy margin of the intrusion represents magma subjected to an extreme temperature gradient and provides an opportunity to test current ideas about thermally driven diffusion (Soret effect) and its role in development of highly evolved silicic magmas by looking for gradients in rare earth element concentration.

Finally, the holes will be used to test and refine application of geophysical techniques to volcanic terranes. Deep drilling in the CSDP thermal regimes effort will rely heavily on geophysics for definition of magmatic targets, yet these techniques are largely untested due to limited drilling of magmatic features. Both electrical and seismic reflection surveys will be run across the dike trend inside and outside the caldera. Results will be compared with "ground truth" from the core holes.

Program Evolution

Intersecting a subsurface intrusion with a drill hole is not a trivial problem, however unambiguous the surface evidence. Therefore, the drilling program will be developed with holes of increasing depth, cost, and target complexity so that results from each hole can be used in design of the subsequent hole. Work was initiated outside the caldera because of ease of access and target definition, relative conceptual simplicity of the geologic environment, favorable drilling conditions due to expected hole stability in granite, and greater likelihood of encountering residual heat from the intrusion at shallow depth due to expected low permeability of the environment. Work within the caldera is planned to lag work in the northern part of the chain by approximately 1 year. Table 2 shows current drilling plans, which are, of course, subject to revision based on drilling results and funding constraints. The present project will culminate with two deep (3-km) holes into the dike, one inside and one outside the caldera. The more immediate goal is to intersect the Obsidian Dome conduit and the northern part of the dike at approximately the 500- and 1000-m levels, respectively. In the remainder of this section, we describe the completed 150-m Obsidian Dome hole and the conduit and dike holes which are in progress.

The first hole was conceived as a relatively low-cost shallow vertical hole to investigate structure and chemistry of the Obsidian Dome. The hole was also intended to address the problems of wire line diamond coring in the flow and underlying stratigraphy in order to design properly the later, more expensive holes. A site near the southern distal end of the flow was chosen because the second hole will penetrate a proximal section of the flow before intersecting the conduit. Comparison of the flow sections sampled by these two holes will permit investigation of the effects of surface flowage on flow structure, bubble growth or collapse, and degassing, and of changes in magma chemistry with time. A truck-mounted wire line diamond core rig of the type commonly used in hard rock mining was employed. Coring was required to meet the scientific objectives of the hole. Further, conventional rotary drilling that relies on return fluid flow to bring cuttings to the surface would have been impossible in the highly fractured dome. Boyles Brothers of Reno spudded the hole on October 20, 1983, and completed it on November 4 at a total depth of 152 m. The hole was cored NC (93-mm diameter) to 124 m, cased NX to 122 m, and then cored NX (76-mm) to 152 m. Surprisingly, little difficulty was encountered penetrating Obsidian Dome, and recovery averaged 90% (close to 100% in the unfractured interior), even though drilling proceeded without circulation. The cost was about $170/m of which $30/m was drilling fluid. The

Article (cont. on p. 724)

TABLE 1. Institutions and Investigators Currently Involved in the Inyo Drilling Program

Institution	Investigators	Investigations
Lawrence Berkeley Laboratory	A. F. White	fluid geochemistry
Lawrence Livermore National Laboratory	N. R. Burkhard, P. W. Kasameyer, L. W. Younker	seismic reflection, thermal/chemical relationships
Los Alamos National Laboratory	J. N. Albright, F. E. Goff, H. D. Murphy	fracturing experiments
Sandia National Laboratories	C. R. Carrigan, J. C. Dunn, J. C. Eichelberger, T. M. Gerlach, P. C. Lysne	volatile geochemistry, thermal modeling
U.S. Geological Survey	R. A. Bailey, C. D. Miller	petrology/geochemistry
Arizona State University	J. H. Fink	structure
Brown University	J. F. Hermance	electromagnetic survey
Michigan State University	T. A. Vogel	thermal/chemical relationships
Stanford University	D. D. Pollard	structure
Canadian Geological Survey	B. E. Taylor	H, C, O isotopes

*Combined list from interlab shallow drilling proposal and Interagency Inyo proposal.

The VGP News

"Mind and Mallet and Crucible"
[Originally appeared in *The Geothermal News*, 9, 5, 1958.]

Editor: Bruce Doe, 11721 Ury River Court, Reston, VA 22091 (telephone 703-860-3470, after 5:30 p.m.).

Understanding Thermal Energy and Dynamic Processes in Subduction-Related Volcanic Arcs: Proposed Studies in the Cascades

George R. Priest and David D. Blackwell

The importance of subduction-related volcanic arcs in the geologic record and in the record of historic earthquakes and volcanic eruptions is hard to overstate. Subduction-related terraces appear to be represented in the geologic record from the Archeozoic to modern times and account for much of the world's volcanic activity. Convergent plate margins stretching for thousands of miles around the Pacific, the Caribbean, the Indian Ocean, and the Mediterranean have some of the most active volcanoes and largest geothermal systems in the world. Many of the world's largest hydrothermal ore deposits are associated with calc-alkaline magmas injected into the crust as a result of the subduction process. The enormous deposits in the Andes, Indonesia, Japan, western North America, and other areas around the Pacific are examples.

The Cascade Range is the only presently active subduction-related volcanic arc in the conterminous United States. Active volcanoes related to the arc occur over a distance of over 1,300 km from British Columbia to northern California. The most destructive historic volcanic eruption in the United States occurred in 1980 at Mount St. Helens in the Washington part of the range. Partly because of its unique status, the Cascade Range is also one of the most completely studied volcanic arcs in the world. In spite of the extensive geologic and geophysical data available for the range, the detailed subsurface geology is essentially unknown because the thick sequences of young volcanic rocks effectively mask deeper structures. The high porosity, permeability, and resistivity and the low seismic velocity of young volcanic rocks in the most active part of the arc make geophysical sounding very difficult.

Geophysical techniques have been much more successful in the Western Cascades than in the young volcanic rocks of the High Cascade Range to the east. The Western Cascade Range is Miocene and older volcanic terrane which has been diagenetically and hydrothermally altered, greatly decreasing the porosity and permeability of the rocks.

One of the most significant findings from studies of the Western Cascade Range is in the area of heat flow. The results of heat flow measurements in numerous drill holes indicate that there is a heat flow anomaly with a half width of approximately 10 kilometers on the western side extending from northern California to southern British Columbia [*Blackwell and Steele*, 1983]. Heat flow increases by as much as a factor of 2 or more across the western side of this anomaly, and the average geothermal gradients within the main part of the anomaly in the Oregon Cascade Range are about 65°C/km [*Blackwell et al.*, 1978, 1982]. On the basis of the interpretation of these data, it appears that temperatures appropriate for partial melting of granitic material should occur at depths on the order of 7 to 10 kilometers under the easternmost part of the Western Cascade range in Oregon [*Blackwell et al.*, 1978, 1982]. These depths are similar to depths estimated for partially molten granitic bodies under silicic volcanic centers such as the Yellowstone, Long Valley, and Valles calderas. Temperatures at equivalent depths beneath the High Cascade Range may be even higher, but thus far attempts to measure heat flow in the High Cascades have been thwarted by the rapidly circulating shallow groundwater which washes away heat flow in the carapace of young volcanic rocks. Lack of reliable heat flow data in the High Cascade Range is one of the principal reasons that its geothermal resources are not generally included in estimates of the accessible geothermal resource base for the United States. If geothermal systems are present in a significant part of this enormous province, they could dwarf the geothermal potential estimated for the largest silicic volcanic centers in the United States.

Rationale for Scientific Deep Drilling in the Cascades

The previously mentioned problems presented by the cover of young volcanic rocks in the Cascades can only be solved by drilling. Experience in drilling in areas such as Newberry Volcano in Oregon has shown that drill holes must generally be 1 km or deeper in order to make meaningful measurements of heat flow in the youngest part of the volcanic arc. Drill holes deeper than 1 km are almost completely lacking in the young volcanic rocks of the High Cascades. Drilling to depths of 7–10 km would be necessary in order to test directly the hypothesis that temperatures near the melting point of granitic rocks occur at those depths. Should this hypothesis prove to be correct, it would have enormous consequences for estimates of geothermal potential and for physical models of subduction-related volcanic arcs throughout the world. It would mean that regional zones of very high temperature, possibly molten rock, occur at relatively shallow crustal levels under the entire length of active arcs regardless of the presence or absence of single large volcanoes. Measurements in drill holes in the Cascades would allow calibration of the extensive surface geological and geophysical surveys, which could then be applied to other, less well-studied arcs of the world. The drilling program would thus test a fundamental hypothesis and provide a standard data base for investigating other similar regions throughout the world.

Program for Scientific Drilling in the Cascades

In recognition of the need for deep scientific drilling in the Cascades, a group of scientists who are actively pursuing research in the province have met several times to formulate a proposal. An initial meeting was held at the AGU conference in San Francisco last December, and a proposal is now in preparation for submission in early 1985. The thrust of the proposed project will be a coordinated program of drilling and surface geological and geophysical surveys along a series of east-west transects across the full width of the Cascade Range. The drilling will occur primarily in the young volcanic terrane of the High Cascades and will be completed in two phases. The bulk of the drilling during the first phase will be aimed at reaching depths of between 1.2 and 2.7 km in two transects of four wells each across two contrasting parts of the arc. Some surface surveys and shallower drilling are also contemplated during the first phase to characterize two lower-priority east-west transects. The four transects are targeted on the southern Washington Cascades, two localities in the central Oregon Cascade Range, and the northern California Cascades. The first phase would allow direct testing and modeling of the hydrothermal systems, measurement of the amplitude of the heat flow anomaly in the High Cascades, and direct sampling of basement rocks to determine the structure, state of stress, and other physical properties. The first phase will also include geologic mapping and a full range of geophysical surveys across both the High Cascades and the Western Cascades to investigate the overall geologic framework of the arc, including the configuration of the subducting oceanic plate and the development of the arc through time. The second phase would be aimed at directly penetrating the source of the regional heat flow anomaly at depths of 7–10 km. The second phase would be an extraordinary scientific and engineering accomplishment and would necessarily be preceded by a lengthy period of research and development. Whereas the proposal currently being prepared deals conceptually with the second phase, only work on the first phase will be addressed in the initial proposal.

The extensive knowledge gained from the proposed research in the Cascade Range will, when integrated with similar data from the proposed Trans-Alaska Lithosphere Investigation (TALI), give an accurate representation of the configuration of the major subducting plates and associated volcanism along the western margin of North America. TALI was recently organized by the U.S. Geological Survey and other groups to plan for drilling and areal studies along a north-south transect 1,400 km long across the full width of Alaska.

This article is partly intended as an announcement to alert various funding agencies and potential colleagues to the existence of the organizing group for Cascade scientific drilling. We invite participation from other scientists at this time or in the future as the activities become more specific. A proposal submission is planned for January or February 1985. If you are interested in participating in this project, you can obtain general information and information on Oregon geologic studies from George R. Priest at the Oregon Department of Geology and Mineral Industries, 1005 State Office Building, Portland, Oregon 97201 (telephone: 503-229-5580). The following persons are coordinating other aspects of the project:

Hydrology: Edward S. Sammel, U.S. Geological Survey, 345 Middlefield Road, M/S 39, Menlo Park, CA 94025.

Water Chemistry: Robert H. Mariner, U.S. Geological Survey, 345 Middlefield Road, M/S 27, Menlo Park, CA 94025.

Hydrothermal Alteration, Geologic Studies in the Northern California Cascades: Terry E. C. Keith, U.S. Geological Survey, M/S 910, Branch of Igneous and Geothermal Processes, 345 Middlefield Road, Menlo Park, CA 94025.

All Work in the Southern Washington Cascades: Craig Weaver, U.S. Geological Survey, Geophysics Program AK-50, University of Washington, Seattle, WA 98195.

Heat Flow: David D. Blackwell, Geothermal Laboratory, 285 Heroy Building, Southern Methodist University, Dallas, TX 75275.

Seismic Surveys: Walter Mooney, Douglas A. Stauber, and Mahadeva Iyer, U.S. Geological Survey, M/S 77, 345 Middlefield Road, Menlo Park, CA 94025.

Gravity and Aeromagnetic Surveys: Richard Couch, Department of Geophysics, School of Oceanography, Oregon State University, Corvallis, OR 97331.

Magnetotelluric Surveys: Harve Waff, Department of Geology, University of Oregon, Eugene, OR 97403.

Resistivity and Other Electrical Surveys: Norman Goldstein, Lawrence Berkeley Laboratory, University of California, Building 50, Room 1140, Berkeley, CA 94720.

Well Logging: Richard Traeger, Sandia National Laboratory, Division 6241, Albuquerque, NM 87185.

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Blackwell, D. D., and J. L. Steele, A summary of heat flow studies in the Cascade Range, *Geotherm. Resour. Counc. Trans. 7*, 233–236, 1983.

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George R. Priest *is with the Department of Geology and Geophysics, Southern Methodist University, Dallas, TX 75275.* David D. Blackwell *is with the Oregon Department of Geology and Mineral Industries, Portland, OR 97201.*

News & Announcements

Lionel Wilson Wins VGP Award

Citation

Lionel Wilson (Department of Environmental Sciences, University of Lancaster, England) has brought physics to volcanology and transformed a largely descriptive and petrological science by development of a quantitative and predictive understanding of eruption dynamics. Lionel's involvement in volcanology started in 1971 when he helped George Walker determine the rates of fall of pyroclasts. This fairly simple problem led to questions of settling of ash particles onto the earth, and Lionel embarked on a series of papers that progressively traced volcanic debris back to its source crater. He described the physical processes affecting pyroclasts in strombolian and plinian eruptions, and with Steve Sparks and others modeled the formation (1976) and emplacement (1978) of ignimbrites by gravitational collapse of an eruption column. In a paper important to understanding the dispersal of tephra, Lionel and others demonstrated that eruption cloud heights are proportional to the fourth root of the mass eruption rate of magma (1978), leading ultimately to the inversion of the problem to deduce cloud height and associated eruption characteristics from mapped tephra distributions. The correctness and utility of Lionel's theoretical descriptions of explosive activity were demonstrated by a series of papers applying the models to actual eruptions at Fuego, Guatemala (1980), Ngauruhoe, New Zealand (1979), La Soufriere, St. Vincent (1982), and St. Helens, Washington (1982), as well as to tephra deposits at Askja, Iceland (1981), Toluca, Mexico (1977), and Thera, Greece (1978).

During the last few years, Lionel has turned his attention to volcanism in other parts of the solar system. Working with Jim Head and associates, Lionel derived mathematical models of the ascent and emplacement of basaltic magmas and applied these ideas successively to earth and moon (1981), Mars (1982), Io (1982), and Venus (1982). A good summary paper appears in *Nature* (*302*, 663–669, 1983). The planetary work represents a testing and application of his models of pyroclastic dynamics to new environments and also the development of similar quantitative understanding of lava flow dynamics. Lionel and Jim Head thus were able to numerically account for peculiar features of lunar sinuous rilles and associated source craters (1981). On Mars, Lionel and coworkers discovered evidence for recent explosive activity on one of the shield volcanoes, and derived the cloud height, mass eruption rate, volatile content, and depth of magma storage (1982). For Venus, there is no direct evidence of the nature of volcanism, although chemical analyses of surface materials and geomorphology give persuasive evidence for past volcanic activity. However, Lionel's numerical models of explosive activity, adjusted to the high temperature and pressure of Venus, provide clues to possible volcanic processes and landforms seen on radar images. Lionel found that energetic eruptions on Io can be modeled if large proportions of volatiles are erupted at high eruption rates (1981).

Lionel Wilson has produced a series of major papers that numerically model nearly all aspects of eruption processes. His collaboration with leading volcanologists and planetary geologists has ensured that his models are geologically reasonable and widely accepted.

As the third winner of the VGP Award, Lionel Wilson provides further evidence for the successful application of fundamental physical, chemical, and mathematical principles to the understanding of geophysical and geochemical processes. (I am indebted to C. A. Wood for most of this citation.)

Joseph V. Smith

Acceptance

I am very grateful for your kind remarks about my work, Professor Smith. When I look at the field of volcanology, I see it with the eyes—and thought processes—of someone whose first interest was in basic physics rather than geology. The question of how we look at things—how we approach problems—has always intrigued me. I wonder if we are attracted to a particular scientific discipline as a result of our personal way of perceiving the world, or if we choose the discipline for some other reason and are then molded by the current conventions of that field. I would like to think it is the former, since the latter has the inherent danger of suppressing new ways of thinking; but I am still not sure.

Many physicists—including me—look at the world in terms of simple processes. I recall once sitting on a cliff top overlooking a waterfall with a friend who was reading mathematics. Just to be provocative I said to her, "When you look at this waterfall, what interests you most? Is it the way energy conservation determines the speed of the water at the bottom in terms of the height of the fall, or is it the way the geometry of the system determines where the rainbow forms in the spray? or what?" I expected a response like, "You physicists are all the same: Why don't you appreciate it just because it's a beautiful view?" But instead she looked down and thought for a moment and said, "Don't you think a waterfall is too complex just to apply energy conservation? You really need the full fluid-dynamics equation to treat a problem like that." Since then, I have felt much happier about the way physicists see the world.

Soon after I was graduated, I realized that it is much more interesting to work on applied problems than purely theoretical ones; this led me toward geophysics in general and quite soon into volcanology as the major theme of my research. I would certainly like to support the comments you made earlier, Professor Smith, about the importance of the interdisciplinary nature of the field, needing as it does input from many branches of geology, physics, and mathematics. I would also stress that as in other areas of earth science, we get a lot of extra information by viewing the earth as just one of a group of silicate planets. Studying eruptions on Io or Mars or the moon allows us to see the consequences of events taking place in environments with different values for the gravity or atmospheric pressure, and this is just a way of applying the classic technique of changing the boundary conditions and seeing how the system responds. I certainly feel that we should all be trying to expose our graduate students to the multi-planet data set as well as to the multidisciplinary approaches we have found so essential.

For those of us who, like me, did not have the benefit of all of these inputs during our early, formative years, the most efficient way of working involves collaboration with colleagues who have complementary backgrounds to our own, and I would like to pay tribute to my geological friends whose field experience and intuition help to keep me from wandering into the realms of fantasy too often. I have particularly benefited from collaboration over many years with the scientists Professor Smith mentioned earlier: George Walker at Hawaii, Steve Sparks at Cambridge, and Jim Head at Brown. I would also like to mention the invaluable support I receive from my wife, Dorothy. She didn't make it to this meeting unfortunately; she found herself choosing between coming to Cincinnati or spending 6 weeks helping me in Hawaii in the summer, and strangely and by a very small margin of course, Hawaii won. Her background is not in science, as it happens, and so she is willing to listen without interrupting for far longer than anyone here in the audience would do to some of my more outrageous ideas. But having listened, she always tells me when something sounds like unmitigated nonsense, which is a great help. So, to the people I have mentioned specifically, to the many other colleagues who continue to provide stimulating ideas and constructive criticism, and to all of you for your kindness in presenting me with this award, my grateful thanks.

Lionel Wilson

Call for Contributions

The deadline for the January 1985 issue of The VGP News is November 30, 1984. Please submit all contributions to Bruce Doe.

Readers are also asked to inform the editor of The VGP News if they are interested in reviewing any recently published books. Input on what types of books and any specific suggestions for which books should be reviewed are also welcome.

Meetings

Microscopic to Macroscopic

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Cover. Coring through a 600-year-old obsidian flow near Long Valley Caldera, Calif. This hole, the first of a series to probe the subvolcanic environment of the Inyo Domes chain, penetrated 55 m of flow and bottomed at 152 m in precaldera andesite. (Photo by J. C. Eichelberger. See article, "Research Drilling at Inyo Domes, Long Valley Caldera, California," by J. C. Eichelberger, P. C. Lysne, and L. W. Younker.)

Article (cont. from p. 721)

Through solubility data for various volatile species, vapor pressure at the time the system chemically closed can be inferred from volatile concentration and compared with the known lithostatic load. By sampling chill zones at multiple depths, the pressure (depth) dependence of degassing behavior can be determined. Alternatively, if no degassing occurs except by explosive fragmentation, volatile content will be independent of depth. For magma under lithostatic load at 1000 m, the solubility of water in melt is an order of magnitude higher than water contents observed in Obsidian Dome. Although it might be expected that degassing would result in water contents near the solubility curve, in fact equilibration with surface conditions (0.1 MPa) extends to at least 100 m (2 MPa) [*Eichelberger and Reece*, 1983]. While degassing to 1 atmosphere water vapor pressure is certainly not expected to extend to depths of 500 or 1000 m, glasses at these depths may be substantially water undersaturated (at magmatic temperature) if the magma behaves during ascent as a stiff, permeable foam.

The problem of dike emplacement will be investigated in detail. Fracture experiments will be used to characterize current conditions in the vicinity of the dike in terms of joint orientation and stress orientation and magnitude. Evidence for the mechanism of dike propagation is provided by fractures and other mechanical damage near the dike. Predictions of fracture distribution from existing dike propagation models (*Pollard et al.*, 1983) can be compared with actual fractures mapped from core examination and bore hole televiewer studies, which may also reveal pathways of fluid flow relevant to the geochemical and thermal investigations.

Processes of mass transport within the dike and between the dike and its host will be investigated largely through trace element and isotopic techniques. The isotopic composition of oxygen and hydrogen is a sensitive indicator to processes involving water, such as magmatic degassing and interaction between meteoric water and magma [e.g., *Taylor et al.*, 1983]. The isotopic contrast between Sierra basement and Inyo magma for Sr and Pb isotopes will provide a sensitive test of the extent of assimilation [e.g., *Doe et al.*, 1969; *Lipman et al.*, 1978]. The glassy margin of the intrusion represents magma subjected to an extreme temperature gradient and provides an opportunity to test current ideas about thermally driven diffusion (Soret effect) and its role in development of highly evolved silicic magmas by looking for gradients in rare earth element concentration.

Finally, the holes will be used to test and refine application of geophysical techniques to volcanic terranes. Deep drilling in the CSDP thermal regimes effort will rely heavily on geophysics for definition of magmatic targets, yet these techniques are largely untested due to limited drilling of magmatic features. Both electrical and seismic reflection surveys will be run across the dike trend inside and outside the caldera. Results will be compared with "ground truth" from the core holes.

Program Evolution

Intersecting a subsurface intrusion with a drill hole is not a trivial problem, however unambiguous the surface evidence. Therefore, the drilling program will be developed with holes of increasing depth, cost, and target complexity so that results from each hole can be used in design of the subsequent hole. Work was initiated outside the caldera because of ease of access and target definition, relative conceptual simplicity of the geologic environment, favorable drilling conditions due to expected hole stability in granite, and greater likelihood of encountering residual heat from the intrusion at shallow depth due to expected low permeability of the environment. Work within the caldera is planned to lag work in the northern part of the chain by approximately 1 year. Table 2 shows current drilling plans, which are, of course, subject to revision based on drilling results and funding constraints. The present project will culminate with two deep (3-km) holes into the dike, one inside and one outside the caldera. The more immediate goal is to intersect the Obsidian Dome conduit and the northern part of the dike at approximately the 500- and 1000-m levels, respectively. In the remainder of this section, we describe the completed 152-m Obsidian Dome hole and the conduit and dike holes which are in progress.

The first hole was conceived as a relatively low-cost shallow vertical hole to investigate structure and chemistry of the Obsidian Dome. The hole was also intended to address the problems of wire line diamond coring in the flow and underlying stratigraphy in order to design properly the later, more expensive holes. A site near the southern distal end of the flow was chosen because the second hole will penetrate a proximal section of the flow before intersecting the conduit. Comparison of the flow sections sampled by these two holes will permit investigation of the effects of surface flowage on flow structure, bubble growth or collapse, and degassing, and of changes in magma chemistry with time. A truck-mounted wire line diamond core rig of the type commonly used in hard rock mining was employed. Coring was required to meet the scientific objectives of the hole. Further, conventional rotary drilling that relies on return fluid flow to bring cuttings to the surface would have been impossible in the highly fractured dome. Boyles Brothers of Reno spudded the hole on October 20, 1983, and completed it on November 4 at a total depth of 152 m. The hole was cored NC (93-mm diameter) to 124 m, cased NX to 122 m, and then cored NX (76-mm) to 152 m. Surprisingly, little difficulty was encountered penetrating Obsidian Dome, and recovery averaged 90% (close to 100% in the unfractured interior), even though drilling proceeded without circulation. The cost was about $170/m of which $86/m was drilling fluid. The

Article (cont. on p. 724)

TABLE 1. Institutions and Investigators Currently Involved in the Inyo Drilling Program

Institution	Investigators	Investigations
Lawrence Berkeley Laboratory	A. F. White	fluid geochemistry
Lawrence Livermore National Laboratory	N. R. Burkhard, P. W. Kasameyer, L. W. Younker	seismic reflection, thermal/chemical relationships
Los Alamos National Laboratory	J. N. Albright, F. E. Goff, H. D. Murphy	fracturing experiments
Sandia National Laboratories	C. R. Carrigan, J. C. Dunn, J. C. Eichelberger, T. M. Gerlach, P. C. Lysne	volatile geochemistry, thermal modeling
U.S. Geological Survey	R. A. Bailey, C. D. Miller	petrology/geochemistry
Arizona State University	J. H. Fink	structure
Brown University	J. F. Hermance	electromagnetic survey
Michigan State University	T. A. Vogel	thermal/chemical relationships
Stanford University	D. D. Pollard	structure
Canadian Geological Survey	B. E. Taylor	H, C, O isotopes

*Combined list from Interlab shallow drilling proposal and interagency Inyo proposal.

Article *(cont. from p. 723)*

only significant drilling pcoblem was an unstable hole in the nonwelded Bishop Tuff, which eventually necessitated casing. The hole terminated in precaldera andesite. Major scientific results concerning the flow were absence of a basal vesicular zone postulated from surface observations [*Fink*, 1983]; a coarsely vesicular zone was encountered at 14.5–21.5 m), evidence of nearly complete degassing to one atmosphere water vapor pressure [*Eichelberger and Westrich*, 1984], and large variations in concentration of certain trace elements (H. W. Stockman and H. R. Westrich, unpublished data, 1984). These results will be reported in a subsequent technical paper. Of interest here is that the hole demonstrated the practicality of small coring rigs as a research tool for probing the Inyo environment.

Plans for the conduit and dike holes are based on these results and are shown schematically in Figures 3 and 4. Both holes are being drilled by Tonto Drilling Company of Salt Lake City, Utah. The primary objective of the conduit hole is to provide the first samples of the intrusive portion of the Inyo system at its most easily accessible point. At the projected depth of intersection of the conduit of 450 m, significant differences from surface samples in terms of degassing and crystallization behavior should already be apparent. Additional important observations will be the size and structure of the conduit and the nonvolatile chemical composition relative to tephra and flow samples.

The position of the conduit is well expressed topographically by the vent region of the flow. The vent region is a 500 × 800-m area of smooth, vertically projecting spines which is elongate along the trend of the Inyo chain and rises 50 m above the general flow surface. The drill site is a bulldozed area within a pumice claim on the flow just west of the vent region. Advantages of this site are ease of access for equipment and favorable geometry for intersecting the conduit from the side by a slant hole. A hole from a more central location in the vent area might simply travel down the funnel-shaped vent without intersecting the quenched margin. A more distant hole would be more expensive and might miss the target altogether. On the basis of observations of exposed fossil conduits, the target is expected to be large (>100 m), particularly in the north-south direction, relative to possible lateral deviation of the hole. Coring of the entire hole is planned, and the hole should be completed by late summer.

With the exception of being slanted, the hole into the conduit of Obsidian Dome (Figure 3) should be similar to last year's vertical hole. Since the conduit hole is deeper, the initial hole size will be larger, thus allowing for more casing steps should they be required. A Bureau of Land Management permit requirement for drilling in geothermal areas is that a casing be set at least at 10% of the final hole depth or at 61 m (200 ft) in this case. After installation and testing of blow-out-preventer equipment, coring ahead will continue through the andesitic flows at a hole diameter of 96 mm. A second string of casing may be set when granite basement is reached. If the hole is stable through the granite and conduit material, the remaining hole will be open and will be 76 mm in diameter. Two additional coring steps are possible should the hole prove to be unstable.

The dike hole will be spudded immediately following completion of the conduit hole. This hole will formally begin the interagency Inyo effort and will involve the full range of scientific investigations outlined earlier in this article. The hole will be sited near Glass Creek, where there is the closest spacing of Inyo vents. The site lies between Obsidian Dome and the Glass Creek Flow and just east of two phreatic explosion craters and one small cratered dome (Figures 1 and 4). Because the dike is expected to be near vertical and trend north-south, the hole will be slanted in the east-west plane so as to laterally traverse the expected zone of intrusion. If the dike is inclined, it most likely dips to the east as the nearby Sierran frontal fault (Hartley Springs) dips to the east. Therefore the chosen drill site is east of the expected dike position, and the hole will dip to the west. The strongest local alignment of features, and therefore the best indication of the position of the underlying dike segment, is formed by a phreatic crater (which we will call Dry Crater) elongated north-south and located just south of Glass Creek; a presumed crater intersected by the first hole; a long, narrow ridge of spines extending southward from the main vent area of Obsidian Dome; and the central depression of the vent area. Hole geometry has been chosen so that the midpoint of the hole will pass directly under Dry Crater and penetrate the Hartley Springs Fault at a point down dip from the small dome which erupted on the fault. An upper limit on the dip of the fault is taken to be 80°E (R. A. Bailey, unpublished data, 1984), and the hole will be designed to reach the fault in this worst case. The hole should thus intersect structures related to at least one and possibly two phreatic craters, one magmatic vent, and a major, active tectonic feature. The design of the dike hole is similar to the conduit hole, except that core will not be taken in the first ~150 m.

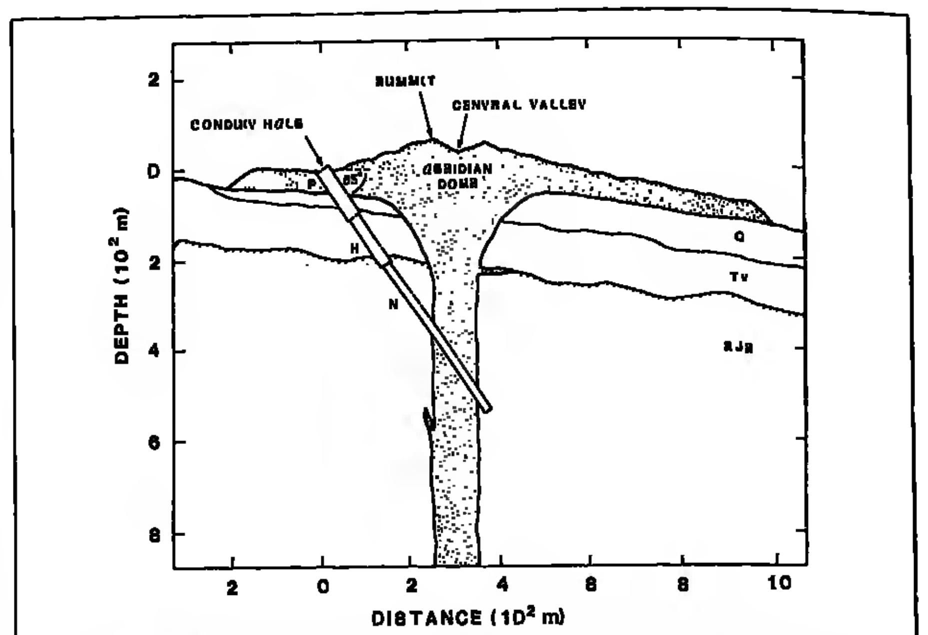

Fig. 3. Cross section II, showing plans for the conduit hole. Hole sizes are P = 123 mm, H = 96 mm, N = 76 mm. Conduit position is inferred from topography on the dome, and conduit size is inferred from fossil analogs. Q is Inyo tephra, colluvium, and Bishop Tuff. Tv is andesitic flows and cinders. KJg is dominantly granodiorite and quartz monzonite. Depth to basement (KJg) is not known, but expected to be shallow.

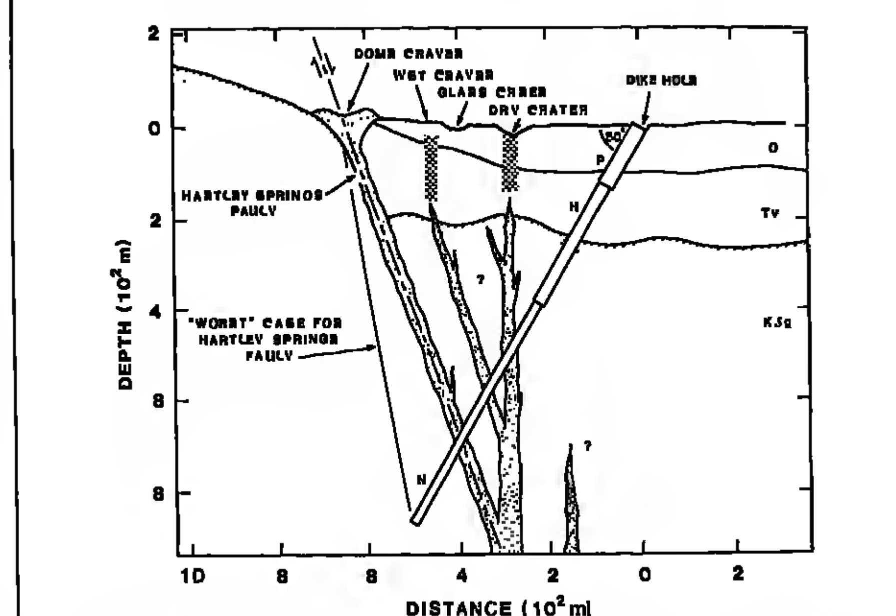

Fig. 4. Cross section III, showing plans for dike hole. Intrusive configuration is speculative, but the hole must pass between vents and the main intrusion. Crater names are informal. Wet crater (dotted) is 200 m north of the section plane.

TABLE 2. Inyo Research Holes

Year	Glass Creek Area (Outside Caldera)	Deadman-Inyo Area (Inside Caldera)
1983 (completed)	150 m vertical core hole, Obsidian Dome	
1984 (in progress)	600 m slant core, Obsidian Dome conduit; 1000 m slant core, dike at Glass Creek	
1985 (proposed)	two 500 m temperature gradient holes near dike; one 150 m seismic observation hole for fracture experiments	1000 m slant core, dike
1986		two 500 m temperature gradient holes near dike
1987	3 km hole	
1988		3 km hole

The dike hole is scheduled for completion in fall 1984. Results of core and borehole investigations will be used to site an array of shallow holes for seismic and further temperature observations and to plan a similar experiment inside the caldera.

Borehole Logging and Instrumentation

The standard suite of logs (electric, nuclear, sonic, and temperature) logs will be run on the conduit and dike wells. In addition, the holes will be surveyed to accurately locate the conduit and dike as well as to provide input data for borehole to surface and borehole to borehole geophysical experiments. Owing to the size of the hole, slim hole logging tools (~50 mm) will be required. Also, the tools will have to be calibrated to obtain rock parameters (porosity, density, etc.) from the measured values of resistivity, neutron, and gamma transport parameters and sonic velocities. In addition to this work, some nonstandard downhole measurements will be made, and three are mentioned below.

A knowledge of the in situ stress is required to generate models for the intrusion of magma into overlying cocks. If hole conditions permit, classical hydraulic fracture techniques can be used to determine these parameters. However, the traditional assumption that the maximum principal stress is vertical is not likely to be valid in the vicinity of the dike. Thus a combination of experiments will be performed. They include an accurate calipering of the hole using a borehole televiewer and a monitoring of the strain relief of oriented core specimens. Both of these techniques have been demonstrated in recent work [*Bell and Gough*, 1983; *Teufel*, 1983].

Triaxial geophones will be cemented into outlying shallow holes (Table 2) to monitor acoustic emission due to fracture propagation during two different fluid injection experiments. The first experiment involves injection of dilute acid into the well in order to induce slippage of preexisting stressd joints. This will permit mapping of joint orientation in the vicinity of the dike well beyond the bore hole. The second experiment, mentioned previously, involves observation of the orientation of fractures formed during injection of fluids at high pressure and hence the orientation of the present stress field near the dike.

A significant contrast in resistivity may exist between the dike and its surroundings. The dike may be significantly less resistive than the crystalline basement if it is porous due to vesicularity or thermally induced fractures. Similarly, high fracture density in the basement adjacent to the dike may make the vicinity of the dike less resistive than the far field. The downhole electrical experiment will consist of a vertical magnetic induction coil used in conjunction with an active source at the surface. It allows determination of formation to surface electrical resistivities away from the borehole and will be useful for both calibrating surface to surface electrical measurements and for "stripping-off" the effect of surficial geology from the signatures of deeper structures. In addition, a number of vertical profiles will be run in each drill hole for a variety of different source field locations and configurations. This allows discrimination among the effects from structures to the side of the drill hole, the formation itself, and structures below the drill hole.

Opportunities for Additional Investigations

Although the effort outlined here is a broad, interdisciplinary program, it does not address every aspect of the subvolcanic Inyo environment. Investigators interested in utilizing the core or borehole in their research are encouraged to communicate with one of the authors of this report.

Author's Note

The conduit of Obsidian Dome was intersected at a slant depth of 487 m on September 6.

Acknowledgments

This report summarizes the combined efforts and plans of geoscientists listed in Table 1. The Inyo pcogram is possible berause of the interest on the part of members of the Office of Basic Energy Science of the U.S. Department of Energy in Continental Scientific Drilling. This work was supported by the U.S. Department of Energy at Sandia National Laboratories under contract DE-AC04-76DP00789 and at Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

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John Eichelberger *received his BS and MS degrees in Earth Sciences from the Massachusetts Institute of Technology in 1971 and his Ph.D. in Geology from Stanford University in 1974. Prior to his employment at Sandia National Laboratories in 1979, he worked at the Los Alamos National Laboratory as a staff member in the Geosciences Group. The current focus of his research at Sandia is on the volatile content of volcanic materials and the role of volatiles in magmatic evolution and eruption. In addition to the Inyo program, he has participated in the drilling activities at Kilauea Iki, Newberry Caldera, and Tonopah Test Range.*

Peter Lysne *received his BA from Grinnell College in 1961. He then attended Arizona State University, which granted him first a NASA traineeship and then a Ph.D. in Physics in 1966. Past activities have included research in thermodynamics as applied to the constitutive relations of solids and liquids at very high pressure and the coordination of geological and geophysical field projects, from which he learned that those who spend nights on drilling rigs must possess a sense of humor. Current research activities deal with neutron logging techniques and the electrical constitutive relations of inhomogeneous materials.*

Leland W. Younker *is a Group Leader at the Earth Sciences Department of Lawrence Livermore National Laboratory. He is currently involved in research on the evolution of high-level silicic systems at both Inyo Domes and southern Nevada as part of the Office of Basic Energy Sciences CSDP project. Earlier projects at Lawrence Livermore included modeling the Salton Sea hydrothermal system, developing remote geophysical techniques for monitoring subsurface fluid movement in geothermal systems, and acting as a support geologist for seismic verification of nuclear test ban compliance. He received his Ph.D. in Geology from Michigan State University in 1974.*

News

Grading Acid Rain Research

The growing concern with the environmental effects of acid rain has spawned a number of study groups in recent years, and now the Office of Science and Technology Policy (OSTP) has released what is essentially a study of a study. In January 1982, White House Science Advisor George Keyworth asked William Nierenberg, Director of the Scripps Institution of Oceanography, and a panel of nine scientists to conduct a peer review of three separate reports on acid deposition in eastern North America that had been turned in by U.S.-Canadian scientific working groups.

Those studies had been requisitioned by a 1980 Memorandum of Intent between the United States and Canada regarding transboundary air pollution. Overall, the Nierenberg peer review panel was "impressed with the efforts of the United States-Canadian Working Groups," (labeled Groups 1, 2, and 3B), but it also found problems. While applauding the work groups' exhaustive search through the acid rain literature, the Nierenberg panel cited what they call an "overdependence on 'soft' literature," or writings such as in-house reports and personal communications, which are outside the publicly available (and carefully scrutinized) body of scientific literature.

Each one of the work groups, the panel believes, could have improved its report. Group 1 reviewed a "huge amount of data. . .but its message was weakened considerably because it did not comply with its fundamental charge to examine squarely the strength of the link between acid deposition and chemical and biological ecological changes." Because the group was unable to agree on a figure for concentrations of sulfates in freshwater lakes and streams below which the water could be considered safe from harmful effects, the Nierenberg panel recommends that they reconvene to develop a "preliminary target loading until better target loading values are available," stating that "the present loading [of sulfates] is too high and that a target loading should be set."

The problem with Group 2's report, according to the panel, is that they depended too heavily on transport models to deduce the relative importances of local and distant sources of sulfur in air and in deposition. It is still too early to rely on the scientific validity of these models, says the Nierenberg panel, at the expense of "traditional scientific approaches." Work Group 3B, on the other hand, "presented a large amount of data on emissions, control techniques and costs, but enclosed it in a report which is difficult to read and harder still to interpret."

The Nierenberg panel's report makes a number of recommendations of its own concerning acid rain research, in compliance with a White House request to provide further research and monitoring recommendations to reduce uncertainties in the scientific and technical knowledge regarding acid deposition. Stating that "large portions of North America are currently being stressed by wet deposition of acids, by dry deposition of acid-forming substances, and by other air pollutants such as ozone, metals, and organics," the panel recommends that "cost effective steps to reduce emissions begin now even though the resulting ecological benefits cannot yet be quantified."

Specifically, researchers should first try to quantify the overall effects of acid deposition, both wet and dry, on an ecological system before trying to distinguish between the two. As a next priority they should then work on "disentangling the effects of acid deposition from those of other anthropogenic atmospheric insults." Other goals for investigation are accurate measurements of dry deposition, network measurements of trace elements and compounds that can point to sources of pollution, and improved understanding of the atmospheric chemistry by which pollutants such as SO_2 are acidified. Once these types of data are collected, the information should then be incorporated into improved computer models, according to the report.

In conclusion, the panel said it was "disappointed at the way in which the Federal Government has been conducting its research program on acid rain," and called for a larger share of research funding to go to non-Federal laboratories and for more emphasis on studying the ecological effects of acid rain. "Although current funding of acid rain studies is much higher than in the past and increasing," the report says, "carefully chosen priorities in fields and investigators can markedly accelerate progress in this difficult field."

New Weather Forecasting Aid

A new, computerized weather analysis and display system developed by the National Oceanic and Atmospheric Administration (NOAA) is being used to provide air traffic controllers in Colorado with up-to-date information on weather systems that could affect aircraft within their control areas. The system, called PROFS (Prototype Regional Observing and Forecasting Services), was under development for four years at NOAA's Environmental Research Laboratories in Boulder, and is undergoing operational evaluation at the Federal Aviation Administration's (FAA's) Denver Air Route Traffic Control Center in Longmont, Colo. FAA officials see the new system as a first step in upgrading the weather support services for the nation's air traffic control system.

Originally created to help National Weather Service personnel with their forecasting duties (*Eos*, April 13, 1982, p. 233), the PROFS system was specially tailored for aviation use before being installed at the Longmont center. The system uses computers to process weather data from satellites, regional radar, wind profilers, a network of automated weather stations in eastern Colorado, and other sources, some of which are not normally available to forecasters. When this information is collected and formatted, weather personnel at the center can choose from several types of visual display on their terminals, depending on what information they require. The forecasters can then make printed copies of any display and distribute them within moments to controllers who use the information to alert air traffic to storms, wind shifts, and other weather disturbances.

An example of the system's usefulness is in providing advanced warnings of quickly developing storms. These storms often make it necessary to close corridors of air traffic. If controllers know ahead of time that a certain corridor will be closed, however, they can make appropriate adjustments and avoid traffic backups. The Longmont center directs air traffic in a region covering all or part of eight western states, and more than 3,000 flights pass through that airspace each day. According to Dan Austin, the center's air traffic manager, the ability "to increase the timeliness and accuracy of forecasts is absolutely vital to our being able to plan our traffic so we don't have to wait for an airplane to stick its nose in a cloud to find out what conditions actually are. [The new system] allows us to get important weather information in real time and lets us take appropriate corrective action at the earliest possible moment."

Several modifications to the PROFS system were made for aviation use, including the addition of one display that relates a storm's location to an aircraft's position, and so allows forecasters to give an air traffic controller direction and distance readings for a storm without having to make the calculation himself. The long-term goal for computerized forecasting systems, according to Dan Austin, is to have weather contours displayed directly on controllers' screens, along with aircraft information.

Corrections

Three references were incorrectly cited in the article entitled "Historic Cartographic Evidence for Holocene Changes in the Antarctic Ice Cover" by John G. Weihaupt, published in the August 28, 1984, *Eos*. In the first column on page 498, both references to Figure 5 should be to Figure 4. On page 499, the reference to the unpublished studies by W. F. Budd should be to personal communication, 1982.

The geographic distribution of AGU members that appeared in the 1984 Membership Directory (*Eos*, August 28, 1984, p. 527) incorrectly listed the membership totals for several countries and inadvertently omitted Ecuador and Israel from the list. The correct membership figures are as follows:

Dominican Republic	2
Ecuador	4
India	42
Indonesia	18
Iran	3
Iraq	5
Ireland, Republic of	11
Ireland, Northern	2
Israel	50

Classified

MARINE ENGINEER/ NAVAL ARCHITECT/ SHIP SYSTEMS ENGINEER

The Office of Naval Research is seeking an experienced Marine Engineer/Naval Architect/Ship Systems Engineer to serve as Head of the Ship Management Office, managing a program of Navy-owned research vessels operated by academic institutions. This is a Civil Service position at the GM-13 level. Salary will range from $36,327 to $47,226, depending on individual qualifications. The position is located at the ONR Detachment on the National Space Technology Laboratory site outside Bay St. Louis, Mississippi. Applicants must have a minimum of three years of professional experience and knowledge of naval architecture and/or marine engineering related to inspection, maintenance and refit of scientific survey or research ships; knowledge of scientific instrumentation associated with such ships; and the ability to review, evaluate and negotiate proposals for major refit, maintenance and overhaul of scientific survey or research ships. Frequent travel is required. Interested persons should submit a resume or Standard Form 171, Personal Qualifications Statement (available at Federal Job Information Centers or from the address below), to:

Office of NAVAL RESEARCH,

Civilian Personnel Division, Code 781SC, Attn: Announcement #84-46 (EOS), 800 North Quincy Street, Arlington, VA 22217. Applications will be accepted through 22 October 1984 and must be received by that date. Applicants are requested to complete the appropriate supplemental forms. For further information and supplemental forms, please call (202) 696-4705.

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Physical Oceanographers. The Physical Oceanography Branch of the U.S. Naval Oceanographic Office seeks full-time Oceanographers for the study of the effects of oceanic currents and thermohaline structure on undersea systems using data collected from various platforms for a variety of projects. The projects involve the collection, analysis and reporting of physical oceanographic data directly applicable to relevant Navy environmental requirements. Up to 50% field duty may be required. Multiple vacancies at the GS-7, 9 and 11 levels are available depending upon qualifications and experience and will remain open until filled. Salary range: $17,221 to $33,130.

Please contact (for required forms): Debra Staples, #N00-78(84), Commercial 601-688-5720, Autovon 485-5720, or FTS 494-5720, U.S. Naval Oceanographic Office, Management & Personnel Division, Personnel Operations Branch, Code 4320, Bay St. Louis, NSTL, Mississippi 39522.

Research Associate. The University of Colorado is advertising a research associate position. The salary for this position is $20,800. The duties and requirements are as follows.

DUTIES: Carries out individual and collaborative basic research studies on small-scale and mesoscale meteorology and its applications on air pollution. Research is likely to include precipitation processes and dynamics associated with convective storms and mesoscale features such as squall lines, fronts and jets, the effect of moist convection on the large-scale environment. Both theoretical and observational studies will be encouraged in conducting this research. The ultimate goals are to improve the forecast, and the applications of the mesoscale model in the transport of air pollutants.

REQUIREMENTS: Ph.D. dissertation or equivalent research contribution in meteorology or related field. Demonstrated expertise/interest in small-scale precipitation processes and mesoscale meteorology. Demonstrated knowledge of and experience in the NCAR/PSU mesoscale numerical modeling. Demonstrated knowledge of tropospheric photochemistry. Extensive use of a large, advanced computer and experience in the design, coding and testing of large numerical models and data processing. Strong mathematical abilities. Demonstrated skill in effective written and oral communication.

APPLICATION: Application materials are as follows: Letter of application, complete resume including publications list, and three letters of reference from professional colleagues. These are to be sent to: The Director, CIRES, Campus Box 449, University of Colorado, Boulder, Colorado 80309.

AA/EE.

Illinois State Water Survey, Champaign, Illinois. The Illinois State Water Survey invites applications for a full-time research position in its Climatology and Meteorology Section. The position involves the development and use of programs for interactive computer analysis of digital radar using a VAX 11/750. Thus strong interest in computer analysis of atmospheric data is desirable. The successful applicant would be part of a research team studying the development and evolution of convective cloud systems.

Applicants should have a degree in Atmospheric or related sciences, with a strong background in computer programming and application *or* a degree in computer science with background in the physical sciences. Academic or practical experience in cloud physics and radar meteorology would be beneficial. Knowledge of FORTRAN is necessary and familiarity with UNIX and/or PASCAL or C programming languages would be advantageous.

The position could begin in Autumn 1984. Salary will be commensurate with experience. Interested applicants should submit a vita, and have three letters of recommendation sent to Dr. Peter Lamb, Illinois State Water Survey, P.O. Box 5050, Station A, Champaign, IL 61820. Call 217-333-1702 for further information. The Illinois State Water Survey is affiliated with the University of Illinois and is located on the University Campus.

It is an equal opportunity/affirmative action employer.

Palaeobiology and Quaternary Palaeoecology Positions/University of Tennessee. The Department of Geological Sciences, UT Knoxville (main campus), invites applications for two tenure track teaching and research positions at the Assistant Professor level.

(1) *Paleobiologist*—Applicants should have research interests in paleobotany, micropaleontology, or invertebrate paleontology.

(2) *Quaternary Paleoecologist*—Applicants should have research interest in terrestrial floras and/or paleoclimatology. This is a 3/4-time appointment made jointly with the Graduate Program in Ecology.

Both positions will be effective September 1, 1985, and applications are due by January 5, 1985. Ph.D.'s are required. Send resume, transcripts, and names of three referees to: Search Committee, Department of Geological Sciences, University of Tennessee, Knoxville, TN 37996.

UTK is an EEO/Title IX/Section 504 employer.

Head/Department of Geosciences. The Pennsylvania State University seeks an academic leader to serve as Professor and Head of a large department with 35 faculty members divided among three academic programs: Geochemistry-Mineralogy, Geology and Geophysics.

A doctor's degree, significant publications and high scholarly standing are required; administrative experience is highly desirable.

Applications will be accepted until October 15, 1984. Applicants should submit a letter of interest and curriculum vitae to:

Arnulf Muan, Chairman
GSr Search Committee
415 Walker Building
University Park, PA 16802.

The Pennsylvania State University is an equal opportunity/affirmative action employer.

Senior Level Hydrogeologist. *Requirements:* M.S. + 5 years experience as Project Manager. Computer modeling and writing skills imperative. Strong background in applied hydrogeology integrated with chemistry and engineering desirable.

Remuneration: Commensurate with experience plus excellent benefits and growth potential.

Respond: In confidence stating interest, full resume, references and salary history to Mrs. V.L. Barsos, R.E. Wright Associates, Inc., 3240 Schoolhouse Road, Middletown, PA 17057.

Executive Director. Executive Director of newly established Incorporated Research Institutions for Seismology (IRIS), a non-profit consortium of about 40 research universities. Initial duties include setting up Washington, D.C. office with associated financial and clerical services, conducting necessary contract negotiations with federal agencies and private organizations, handling procedures and arrangements for extensive committee activities, and working with the managers of the various research programs. Under supervision of the President, represents the corporation as necessary in dealing with member institutions, funding agencies and contractors in administering large scientific programs. The corporation anticipates a level of research exceeding $20 million annually in five years, with a permanent office staff of up to ten. Candidates must be able to work independently, with little staff support in the first year, and have sufficient breadth and experience to establish an efficient, functioning corporate office. Applicants should submit resumes and names of at least three references to: IRIS, Inc., Department EO, 2000 Florida Avenue, N.W., Washington, D.C. 20009.

IRIS is an equal opportunity employer.

Solid Earth Geophysicist. Faculty position at the Graduate Department of Scripps Institution of Oceanography and the Institute of Geophysics and Planetary Physics. Applications are invited for a tenure track faculty position in the field of solid Earth geophysics, including its theoretical and observational aspects. The position will involve graduate level teaching and the supervision of graduate student research. Qualifications include a Ph.D. in one of the sciences and demonstrated excellence and independence in research. Weight will be given to evidence of superior teaching ability. An appointment at the Assistant Professor level is envisaged but qualified applicants at all levels will be considered. Associate or professorial level candidates must demonstrate a strong research record in their specialty; assistant level candidates will be expected to show evidence of their potential by means of a publication record appropriate for their experience and in their letters of recommendation. Salary commensurate with qualifications and experience. Send letter of application, curriculum vitae, including research interests, and the names of three references to: Chairman, Graduate Department A-008, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA 92093. Responses must be received by November 30, 1984.

An equal opportunity/affirmative action employer.

University of Texas at Austin. The Department of Geological Sciences seeks to fill tenure track positions effective fall 1985 in one or more of the following disciplines: 1) micropaleontology-Tertiary biostratigraphy, 2) structure-tectonics, 3) hydrogeology, and 4) mineralogy-kinetics. Each person is expected to teach both undergraduate and graduate courses and to conduct a vigorous research program, including the supervision of graduate students, in the area of his or her specialty. The positions require the Ph.D. degree. Applicants should submit a detailed resume, names and addresses of five references, a statement of teaching and research interests, and a copy of their dissertation abstract by December 1, 1984 to: Dr. William L. Fisher, Department of Geological Sciences, the University of Texas at Austin, Austin, Texas 78713–7909.

The University is an equal opportunity/affirmative action employer.

GROUND WATER HYDROLOGIST

Environmental Science & Engineering, Inc. a full service engineering consulting firm based in Gainesville, Florida, with regional offices in Florida, St. Louis, Denver, Baton Rouge and Anchorage, has openings for ground water hydrologists to manage projects, prepare proposals, and make presentations to clients. Projects include hazardous waste investigations and remedial engineering, ground water monitoring and contamination assessment, geophysical studies, ground water supply development and permitting, and land application of waste water. Requirements include MS Degree in hydrogeology, geology or engineering and 3–5 years experience involving hydrogeology, hazardous waste and water resource.

Environmental Science & Engineering, Inc.
Department EO3
P.O. Box ESE
Gainesville, Florida 32602

Equal Opportunity Employer

University of Utah: Structural Geology/Tectonics/Tectonophysics. The Department of Geology and Geophysics at the University of Utah seeks applications for a tenure track position in structural geology, tectonics or tectonophysics. It is anticipated that this position will be filled at the assistant professor level, but applications by more senior persons will be considered. The position requires a Ph.D. with emphasis in structural geology, regional tectonics or tectonophysics. The new faculty member will have the opportunity to teach in the area of his or her specialty and may also be assigned introductory level courses. The successful candidate will be expected to establish a vigorous research program involving graduate students. The person who fills this position will join an active program in structural geology and tectonics that includes both field projects and integrated geology/geophysics and mechanics/fluid chemistry studies of structures in the western Cordillera. There is an excellent opportunity to collaborate with other faculty in structural geology, sedimentology, geophysics, geochemistry and petrology. A vita, copies of publications, names of three persons that may provide references, and a letter outlining the candidate's research and teaching interests should be sent to Dr. William P. Nash, Chairman, Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah 84112–1183. Deadline for receipt of applications is December 31, 1984 with the appointment starting in September 1985.

The University of Utah is an equal opportunity/affirmative action employer.

Geophysicist/University of North Carolina. The Department of Geology invites applications for a tenure track faculty position in solid-earth geophysics beginning July 1, 1985. The position probably will be at the assistant professor level, but candidates at the associate professor level will be considered. The Ph.D. is required, and post-doctoral experience is desired. Our preference is for a seismologist and/or tectonophysicist, who would complement current departmental activities, but any good applicant in geophysics will be considered.

Faculty members are expected to conduct a visible and active research program, teach graduate and undergraduate students, and supervise theses.

Inquiries and letters of application should be sent to P. Geoffrey Feiss, Department of Geology 029A, University of North Carolina, Chapel Hill, NC 27514. Applications must include resume, statement of research and teaching interests, and the names of at least three referees. Closing date for applications is October 18, 1984.

UNC is an affirmative action/equal opportunity employer.

Department Head of Plant Sciences/University of Nevada Reno. The College of Agriculture, University of Nevada Reno, is seeking applicants for this twelve-month tenure track position. The Department has nineteen faculty and conducts teaching, research and extension programs in the areas of agronomy, horticulture and integrated pest management. A Ph.D. in a plant science related discipline and evidence of administrative and leadership abilities are required. Closing date for applications is October 15, 1984. The position is available January 1, 1985. Contact Dr. Elwood Miller, Chairman, College of Agriculture, UNR, Reno, NV 89557–0004, 702-784-6611.

The University of Nevada Reno is an equal opportunity employer.

Structural Geologist/Ohio State University. The Department of Geology and Mineralogy of Ohio State University invites applications for a tenure track position for a structural geologist with significant field experience, a strong theoretical background, interests in regional tectonics, and familiarity with seismic interpretation. The successful applicant will be expected to participate in the undergraduate program including field courses, teach graduate courses in his/her field of expertise, supervise graduate students, conduct research, and interact with other departmental programs in regional geology and geophysics. Consideration will be given to candidates with industrial experience. A Ph.D. degree is required. Rank will be either assistant or associate professor and rank and salary will be commensurate with experience and research record. Please send applications to:

Chairman
Structural Geology Search Committee
Department of Geology and Mineralogy
The Ohio State University
Columbus, OH 43210.

Applications should include a resume and a statement of research interests. Applicants should arrange to have at least three confidential letters of recommendation sent to the committee. The closing date for applications is December 1, 1984; appointments will be effective October 1, 1985.

The Ohio State University is an equal opportunity/affirmative action employer.

College of Geosciences/University of Oklahoma. Applications and nominations are invited for the position of Director of the School of Geology and Geophysics. The Director is expected to have a Ph.D. or equivalent, a strong, ongoing research program and administrative experience; industrial experience helpful; field of geological specialization open; to begin July 1, 1985; salary to be negotiated.

In 1986, the School will move into the new 300,000 sq. ft. Energy Center along with other elements of the College of Geosciences; the Oklahoma Geology Survey; and the School of Petroleum and Geological Engineering and the School of Chemical Engineering and Materials Sciences, both from the College of Engineering.

Applications with curriculum vitae, names and addresses of three references, and/or nominations should be sent to:

Francis G. Stehli, Dean
College of Geosciences
University of Oklahoma
601 Elm Street, Room 438C
Norman, OK 73019.

Consideration of applications will begin January 1, 1985.

The University of Oklahoma is an Equal Opportunity/Affirmative Action Employer.

Postdoctoral and Research Associate Positions/INSTOC. The Institute for the Study of the Continents (INSTOC) invites applications for postdoctoral and research positions in programs involving study of the continental crust, including COCORP, or to initiate new programs of crustal study. The Ph.D. is required, and experience in geophysics or geology is desirable. Send vitae, list of publications, and letters of recommendation to Professor Jack Oliver, Institute for the Study of the Continents, Snee Hall, Cornell University, Ithaca, NY 14853.

An equal opportunity/affirmative action employer.

The University of Kansas/Faculty Positions. The University of Kansas, Department of Geology seeks to fill three tenure track positions at the Assistant Professor level to begin in Fall, 1985. The Department seeks persons committed to academic careers involving teaching, research, and service. Salaries will be determined by qualifications and experience and will be competitive. Candidates should hold the Ph.D. degree in Geological Sciences or have it near completion.

All positions carry responsibility for teaching at both undergraduate and graduate level, conducting active programs of research and publication, and supervising the research of students. Candidates should expect to teach introductory courses as well as in their specialties. The Department may give preference to those who are qualified physically and by training or experience to teach in our summer field program and have the capability to use the computer to solve geological problems.

Position 1. Sedimentation, with interests in the interface between sedimentary processes and stratigraphy, diagenesis and low-temperature geochemistry, or tectonics. Duties will include teaching courses in stratigraphy, sedimentation, sedimentary geochemistry, or tectonics.

Position 2. Tectonics, with interest in the interface between tectonic processes and sedimentation, igneous phenomena, or metamorphism. Duties will include teaching courses in structural geology and tectonics or petrology. Candidates with field orientation will be preferred.

Position 3. Geophysics, with interests in seismology, crustal structure, or potential fields. Candidates should expect to interact with a strong group in the Kansas State Geological Survey and coordinate the academic aspects of the program in geophysics. Duties will include teaching courses in geophysics, crustal structure, or tectonics.

Applicants should send a resume, academic transcripts, and at least three letters of recommendation to: M.E. Bickford, Chairman of Search Committee, Department of Geology, University of Kansas, Lawrence, Kansas 66045–2124. Application materials must be received by 5:00 p.m. November 19, 1984. The positions are contingent upon availability of funds.

The University of Kansas is an AA/EEO employer and encourages applications from all qualified persons.

MATHEMATICAL GEOLOGIST

Ph.D. degree in earth sciences plus experience in developing computer programs for geological modeling required for an opening in Conoco's Exploration Research Division. Should be able to integrate rock properties, fluid flow, thermal history, etc. in computer models to answer questions of exploration significance. Experience with numerical modeling techniques a plus. Conoco offers an excellent compensation package including relocation assistance and continuing opportunities for professional responsibility and growth. Applicants must be U.S. citizens or have a permanent resident visa. Qualified candidates send resume to:

Marilynn Jackson
Research and Development
Conoco Inc.
P. O. Box 1267
Ponca City, OK 74603

No Agencies, Please
An Equal Opportunity Employer, M/F

CONOCO

Assistant Professor/Atmospheric Sciences. A tenure track assistant professor position will be available in the fall of 1985 at the University of Kansas. Applicants for this position must have a Ph.D. in meteorology or atmospheric science, capability and interest in teaching synoptic meteorology at the advanced undergraduate level, and a strong interest and potential for developing an active research program. Preferred qualifications include postdoctoral research experience and a strong publication record. Duties of this position will include teaching undergraduate meteorology in a B.S. degree program, conducting a vigorous research program, and participating in the responsibilities of the Department of Physics and Astronomy. Salary will depend upon qualifications. Qualified applicants are invited to submit resumes or curricula vitae, bibliographies, narrative statements of research and teaching interests, and the names, addresses, and telephone numbers of three references to Professor J.P. Davidson, Chairman, Department of Physics and Astronomy, University of Kansas, Lawrence, KS 66045. The closing date is November 15, 1984.

An affirmative action/equal opportunity employer. Applications are sought from all qualified people regardless of race, religion, color, sex, disability, veteran status, national origin, age or ancestry.

Old Dominion University/Marine Organic Geochemist—Search Extended. The Department of Oceanography seeks candidates for a newly created, state-funded tenure track faculty position in marine organic geochemistry. Specific research interest is open, although the major departmental emphasis is on coastal processes. The successful candidate is expected to pursue a vigorous funded research program, and to teach undergraduate and/or graduate level courses in his/her field. The expanding Oceanography Department offers programs leading to the M.S. and Ph.D. degrees. It currently has 15 faculty positions, with three in chemical oceanography, 70 graduate students, and the appropriate facilities for many chemical studies. The position will be at the assistant professor level. A Ph.D. is required and post doctoral experience is desirable. The position is available for the 1985–86 academic year. Applicants should submit a vita, statement of research interests, and the names of three references by October 31, 1984 to: Dr. Gregory A. Cutter, Search Chairman, Department of Oceanography, Old Dominion University, Norfolk, VA 23508, 804-440-4285.

ODU is an affirmative action/equal opportunity institution.

Manager, Research Computer Facility. The University of Oklahoma is looking for a person to manage a recently purchased VAX 11/785 computing facility dedicated to research in the Geosciences. Hardware and Software are designed for image processing, seismic reflection data processing, and graphical display of geological, geographical and geophysical data.

In addition to the 11/785 with 8mb of CPU memory, the system includes an array processor, five tape drives, five disk drives, a line printer, a 36" electrostatic plotter, and two high resolution graphics work stations with a digitizing board. The image processing hardware includes a Gould-DeAnza IP8500 processor with 16 image memory planes, real time disk memory and three high resolution color monitors.

The person selected must have at least a BS degree in science, math, engineering or related field; two years programming experience including FORTRAN; educational or computing experience in solid earth geophysics or meteorology. Experience with the VAX VMS operating system as well as supervisory experience are desired.

Salary is negotiable. People interested in the position should send a resume, copies of academic transcripts, and the names, addresses and telephone numbers of three references to:

John Wickham, Director
School of Geology & Geophysics
University of Oklahoma
Norman, OK 73019

Applications must be received by November 2, 1984.

Hydrogeologist/Texas A&M University. The Department of Geology and Center for Engineering Geosciences have a tenure track opening, preferably assistant professor level, for which the first search will be for a creative individual working in applied geological hydrology.

The successful applicant will be expected to develop teaching and research recognition at a national level. The position is available beginning September 1, 1984 and will be held open until filled. Applicants should submit a vita including names of references to M.C. Gilbert, Department of Geology, Texas A&M University, College Station, TX 77843.

Texas A&M University is an affirmative action/equal opportunity employer.

Postdoctoral Position/Naval Postgraduate School. The Ocean Turbulence Laboratory has available a postdoctoral position for a person interested in the analysis and interpretation of oceanic turbulence data. The tenure is for one or two years. The successful candidate should have a Ph.D. in physical oceanography and although experience with turbulence data is preferrable it is not essential. The opportunity for involvement in data gathering expeditions is also available. Resumes can be sent to Dr. R.G. Lueck, Code 68 Ly, Naval Postgraduate School, Monterey, CA 93943.

AA/EOE.

Congressional Science Fellowship. Opportunity for a one-year assignment (September to August) on the staff of a congressional committee or a House or Senate member as an advisor on a wide range of scientific issues affecting public policy questions.

Individuals who are AGU members and U.S. residents are invited to apply. A broad background in science is expected, as the various duties entailed require the applicant to be articulate, literate, flexible, and able to work well with people from diverse professional backgrounds.

Public policy background is not required although such experience and/or demonstratable interest in applying science to the solution of public problems is desirable.

The fellowship carries with it a stipend of up to $28,000 plus travel allowances.

How to apply:

Candidates should submit a letter of intent, a curriculum vitae, and three letters of recommendation. The letter of intent should include a statement of why the fellowship is desired, how you qualify for it, what issues and congressional situations interest you, what role you envision as a congressional science fellow, and what outcome you hope for in relation to career goals. The individuals from whom you request letters of recommendation should discuss not only your professional competence, but also other aspects of your background that make you particularly qualified to serve as a Congressional Science Fellow.

Send the above to: Member Programs Department, Congressional Science Fellowship Program, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, D.C. 20009.

Application Deadline: April 1, 1985.

DEAN
College of Marine Studies
UNIVERSITY OF DELAWARE

Applications and nominations are invited for the position of Dean of the College of Marine Studies of the University of Delaware. The preferred starting date is February 1, 1985, however, this is negotiable.

The College of Marine Studies has programs in four interdisciplinary areas: Marine Policy, Marine Biology and Biochemistry, Applied Ocean Science and Oceanography. The College offers the degrees of Master of Science, Master of Arts, Master of Marine Policy and Doctor of Philosophy.

Minimum qualifications for the position include: an earned doctorate in any of the areas represented in the College and broad experience in Marine Studies; significant administrative experience, such as, but not limited to, department chairperson or dean; a record of scholarly publications in Marine research, teaching and public service; and demonstration of outstanding leadership capabilities with a broad vision for the continued improvement of the College's research, educational and service activities.

Nominations or a letter of interest and resume should be sent by October 30, 1984, to: Dr. U. Carl Toensmeyer, Chairperson, Search Committee, Department of Agricultural and Food Economics, UNIVERSITY OF DELAWARE, Newark, DE 19717-1303.

The University of Delaware is an Equal Opportunity Employer which encourages applications from qualified minority groups and women.

Research Geophysicist. The U.S. Geological Survey (USGS), Office of Earthquakes, Volcanoes, and Engineering, Branch of Seismology is soliciting interest from exceptionally well-qualified persons with either a record of demonstrated ability or outstanding potential for research in one or more areas of Branch activity. The Branch of Seismology conducts fundamental research in the fields of earthquake prediction, network seismology, crustal structure and volcano seismology. The Branch is particularly interested in a geophysicist with expertise in the field of seismology.

All interested persons should submit a detailed resume of education, experience, summary of interests and research intentions, and the appropriate salary to:

William Ellsworth
U.S. Geological Survey
Branch of Seismology
345 Middlefield Road, MS-977
Menlo Park, CA 94025

Should a position become available in the Branch, you will be notified of the competitive Federal employment application requirements.

The U.S. Geological Survey is an Affirmative Action/Equal Opportunity Employer.

POSITIONS WANTED

Geologist/Geochemist. 33, M.A., Ph.D. 1983. Specializing in low temperature geochemistry and geochronology with extensive experience in Rb-Sr mass spectrometry. Several publications. Seeks industry, academic research, or government position. Box 027, American Geophysical Union, 2000 Florida Avenue N.W., Washington, DC 20009.

AGU GAP

AGU Membership Applications

Applications for membership have been received from the following individuals. The letter after the name denotes the proposed primary section affiliation.

Paul E. Argo (SA), Richard D. Bagenz (G), Charles R. Bailey (H), Joseph E. Barron (G), Christopher Bowland (T), Bradley A. Bryan (H), Bryan C. Chaknumakns (V), Raymond L. Chuan (A), Robert B. Cunk (O), Keith S. Davidson (H), Kevin F. Dennehy (H), Gregory L. Duckworth (S), Ingvar B. Fridleifsson (V), Dennis R. Helsel (H), Shu-Li Huang (H), Laurel Izmirian (H), George A. Jackson (O), Hiroshi Kawamura (O), Thomas Kunze (S), Gero Kurat (P), Jon Lea (H), Michael S. Librizzi (T), James J. Lienkaemper (T), F. E. M. Lilley (GP), Omar A. Lucero (A), Isao Matsunaga (T), James A. Mercer (O), Theologus M. Mimides (H), Raymond W. Mitchell (V), Harsh Mohan (G), Robert L. Peshkin (H), Michael Planert (H), Lee E. Plansky (T), Jonathan S. Price (H), B. Ranken (S), Robert D. Rowe (G), Jamshid Sadeghipour (H), Edward S. Sarachik (O), Robert T. Shin (H), Kunio Shirasawa (O), Patricia Showalter (H), David M. Silver (O), Donald P. Smith (O), Michael C. Spillane (O), Peter A. Stone (H), Calvin T. Swift (O), Chang-Hue Tsao (SC), Inne L. Vuris (A), Richard J. Warburton (G), C. Gary Wolff (H), J. S. Wroblewski (O), Harry H. Yeh (O).

Students

Boyd Allen (A), Moustafa Baraka (G), Theresa Bodus (A), Mitchell Brourman (H), RM Fadjar M. Budidjanto (T), Rebecca W. Carmody (V), James J. Connors (T), Peter De Menocal (O), Lee Di Tullio (T), Joe A. Drapeau (S), Tracy Evens (H), Joanne Fredrich (S), Timothy M. Gilpin (A), Jenny Glasser (S), Nancy S. Griffin (S), Per O. J. Hall (O), Robert Hamwey (SA), Gregory Hanson (H), Kade J. Howard (V), Michael Glen Hughes (O), Junko Kazumi (O), Jonathan P. Kim (O), G. S. Laird (H), Leo R. M. Maas (O), Arun Majumdar (V), Barbara Matz (S), Diane Miller (H), Bert Mueller (O), Bernard Pelchat (O), Rebecca Renner (V), Haga I. Ron (GP), Mark Sands (SM), Gregory T. F. Shea (V), Ziv Sirkes (O), Helge Skatun (A), Alan David Smith (V), Mark D. Tunnicliffe (O), Alan ...nski (V), E. Paul Vicenzi (V).

Separates

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Particles and Fields—Ionosphere

5535 Interactions between waves and particles
THEORY OF SPECTRAL ASYMMETRIES AND NONLINEAR CURRENTS IN THE EQUATORIAL ELECTROJET
R. Sudan (School of Electrical Engineering, Cornell University, Ithaca, New York, 14853), D. T. Farley and S. G. Fejer

The spectral up-down asymmetry of type-I echoes returned from the equatorial electrojet irregularities is shown to be a consequence of the nonlinear development of the horizontally propagating large scale primary waves which dominate the k-spectrum of the electrojet turbulence. The waves reduce the vertical electric polarization field of the electrojet and suffer second harmonic distortion as they grow. These effects together could cause an asymmetry exceeding 20% between the upward and downward components of the velocities (to the ions) electron velocity associated with the primary waves. This asymmetry, which changes its direction from day to night as does the horizontal electrojet current, could easily account for the radar observations. The modification of the vertical polarization field also limits the perturbed vertical electron velocity to a value about the same as the mean horizontal electron velocity, which should explain why type I echoes are observed in all directions only when the mean electron velocity is supersonic. Finally, this modification of the polarization field amounts to a significant reduction in the electrojet conductivity, an effect which should be included in electrojet models.

J. Geophys. Res., A, Paper 4A0098.

5560 (Particle precipitation)
PRECIPITATION OF RADIATION BELT ELECTRONS BY MAN-MADE WAVES: A COMPARISON BETWEEN THEORY AND MEASUREMENT
U. S. Inan, (STAR Lab, Stanford University, Stanford, CA 94305), H. C. Chang, R. A. Helliwell, W. L. Imhof, J. B. Reagan, M. Walt

The temporal and spectral shape and the absolute flux level of particle pulses precipitated by a VLF transmitter are examined from a theoretical point of view. A test-particle model of the gyroresonant wave-particle interaction is applied to the parameters of the observed cases for calculating the precipitation characteristics. The temporal shapes of the precipitation pulses are found to be controlled (i) by the pitch angle dependence of the particle distribution near the edge of the loss cone and (ii) by the multiple interaction of the particles with the waves due to significant atmospheric backscatter. (Particle precipitation, VLF waves, gyroresonance).

J. Geophys. Res., A, Paper 4A0162.

5461 Plasma motion, convection, or circulation
POLAR CAP INFLATION AND DEFLATION
G. L. Siscoe and T. S. Huang (Department of Atmospheric Sciences, University of California, Los Angeles, CA 90024)

Dayside and nightside merging rates usually differ; first one dominates then the other to maintain long-term flux balance. The polar cap, defined as the area in the ionosphere penetrated by open field lines, expands when closed field lines open during dayside merging and contracts when open field lines close during tail merging. The patterns of convection, electric field and current for polar cap inflation and deflation differ from those of steady state convection. This report models the flow and electrical parameters of polar cap inflation and deflation. We treat the idealized case of uniform conductivity, a planar ionosphere, and "pure B_z" merging (i.e., no B_y effect, although we note how the approach used here is readily modified to account for the B_y effect.) For this idealized case, the potential associated with polar cap inflation and deflation is seen to be described by the same equations that govern the two-dimensional hydrodynamic flow into and out of an expanding and contracting cylinder with a gap in its side. The gap corresponds to the breach in the polar cap boundary through which magnetic flux passes as a result of merging. The calculated potential pattern displays the usual two cell convection configuration, but the foci of the two cells are the edges of the flux gaps. Thus the cells are displaced sunward during dayside merging and tailward during tail merging.

J. Geophys. Res., A, Paper 4A1157.

Physical Properties of Rocks

5110 Elasticity, Fracture and Flow
IN-SITU STRESS DETERMINATION FROM HYDRAULIC INJECTION TEST DATA
F.H. Cornet (Institut de Physique du Globe, Univ. PARIS 6 F5230 PARIS CEDEX 05, France) and B. Valette

Laboratory and field results have shown that the orientation of a hydraulically propagated fracture is not always perpendicular to that of the minimum principal stress but may be influenced by local weakness planes such as preexisting natural fissures; the lower the flow rate the stronger the weakness planes influence. This observation has led to a new stress determination method based on measurement of the normal stress supported by fracture planes, with various dips and strikes. This new method provides means to evaluate the precision of the stress determination and can be applied to situations in which none of the principal stresses is vertical. When all the fracture planes are parallel to the borehole axis, the method is still applicable if fast flow rate reopening pressures can be measured and if the principal stress directions are assumed to be independent of depth. Validity of the method is illustrated by analyzing two sets of data, one of which has been discussed previously in the literature.

J. Geophys. Res., B, Paper 4B1136.

5110 Elasticity, fracture and flow
THE ROLE OF WATER IN THE DEFORMATION OF DUNITE
P.N. Chopra and M.S. Paterson (Research School of Earth Sciences, Australian National University, Canberra).

Specimens of two natural dunites (Anita Bay, of 100 μm grain size, and Åheim, of 900 μm grain size) have been deformed in experiments at temperatures between 1200° and 1400°C and constant strain rates between 10^{-4} and 10^{-6} s^{-1} in a gas-medium deformation apparatus at 300 MPa confining pressure. Prior to these experiments the specimens were given a heat treatment in a controlled oxygen fugacity furnace at 1200°C for >60 hours to dehydrate the trace layer silicate minerals present and drive off adsorbed water. The predried specimens are much stronger than specimens tested under wet conditions in an earlier study. The predried specimens also do not show the apparent grain size dependence seen under wet conditions. Infrared absorption measurements on the present specimens and those of the earlier study indicate that for a given rock, flow stress can be correlated with the intensity of a residual "water related" broad absorption. The addition of water to a predried specimen results in both a mechanical reweakening and an intensifying of the broadband infrared component. The weakening of the dunites under wet conditions is probably strongly influenced by the presence of small amounts of a water-related species in the grain boundaries, but intragranular weakening may also be contributing. It is suggested that the concentration of the water-related species in the grain boundaries is governed by the concentration in the small melt fraction present. The amounts of water that have been found to be of importance for the strength of these dunites are of the order of 0.01 wt%, amounts much less than most estimates of the water content of the earth's undepleted upper mantle. Such water may have an important role in determining upper mantle flow behavior.

J. Geophys. Res., B, Paper 4B0632.

Social Sciences

7310 Economics (policy evaluation and allocation models)
MODELLING EFFICIENT WATER ALLOCATION IN A CONJUNCTIVE USE REGIME: THE INDUS BASIN OF PAKISTAN
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Efficient resource use where ground and surface waters are used conjunctively may require special policies to rationalize the interaction between water use by farmers and the response of the stream aquifer system. In this paper, we examine alternative policies for achieving more efficient conjunctive use in the Indus Basin of Pakistan. Using a simulation model which links the hydrology of a conjunctive stream aquifer system to an economic model of agricultural production for each of 53 regions of the basin together with a network model of the flows in river reaches, link canals and irrigation canals, we have studied the joint effect of various canal water allocation and associated private tubewell tax or subsidy policies on overall system efficiency. The results suggest that large gains in agricultural production and employment are possible, given more efficient policies. (Conjunctive use, water allocation).

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